MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY OF

PART OF

EAST LINCOLNSHIRE,

INCLUDING THE

COUNTRY NEAR THE TOWNS OF LOUTH, ALFORD, AND SPILSBY.

(EXPLANATION OF SHEET 84.)

BY

A. J. JUKES-BROWNE, B.A., F.G.S.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY.

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CONTENTS.

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ILLUSTRATIONS.

PREFACE.

THE present Memoir describes the Geology of that part of Lincolnshire which, lying north of the Wash, embraces the southern half of the Wolds. It gives a detailed account of the various formations from the Kimeridge Clay to the top of the Middle Chalk. The subdivisions established by Professor Judd among the Lower Cretaceous (Neocomian) rocks of Lincolnshire have been adopted by the Geological Survey, as well as his name of "Tealby Beds" for the Middle Division of that series. The name of "Spilsby Sandstone" is proposed for the Lower Division. The upper group or Carstone here generally consists of mere loose sand. The several subdivisions of the Chalk in this region are now for the first time compared with those which have been worked out by the Survey in Buckinghamshire and Cambridgeshire.

A full description is likewise given of the Glacial Deposits which occupy the lower grounds flanking the Wolds, but for his theoretical views, which are not always in accord with those of his colleagues, the author of the Memoir is himself responsible. In connexion with the superficial deposits, he has discussed the comparative age of the several valley-systems of the district.

Among the facts of economic importance described in the following pages reference may be made to the discovery of two horizons of ironstone and also a seam of phosphatic nodules of good quality. A large number of well-sections bearing on the question of water supply will be found in the Appendix.

ARCH. GEIKIE.

Geological Survey Office,
6th December 1886.

NOTICE.

THE larger portion of the country comprised within Sheet 84 was surveyed by Mr. A. J. Jukes-Browne.

Mr. Strahan is responsible for the western part of the Neocomian tract and for the western part of the Jurassic area as far south as Moorby, of which he has also supplied descriptive notes.

Mr. Penning had previously been over and in part mapped small areas near Mablethorpe, Sutton, and Markby; Mr. Skertchly had also partially examined some of the ground in the southern part of the map; but for both these districts Mr. Jukes-Browne is now responsible.

The Appendix on the Fossils is founded upon lists drawn up by Messrs. G. Sharman and E. T. Newton, from the collections made by Messrs Allen and Rhodes for the Geological Survey.

A list of the works relating to the Geology of Lincolnshire has been already given in the Geological Survey Memoir on Sheet 70.

H. W. BRISTOW,
Senior Director.

Geological Survey Office,
28, Jermyn Street, S.W.
1st December 1886.

THE GEOLOGY

OF PART OF

EAST LINCOLNSHIRE,

INCLUDING THE

COUNTRY NEAR THE TOWNS OF LOUTH, ALFORD, AND SPILSBY.

CHAPTER I.

GENERAL DESCRIPTION OF THE DISTRICT.

Geographical Description. Sheet 84 of the Geological survey map includes a portion of Lincolnshire which lies north of the Fenland and abuts upon the shores of the German ocean. Its area contains about 370 square miles of land. The district is traversed by two lines of watershed, (1) that of the Chalk Wolds which commences near Candlesby and runs north-westward, passing into Sheet 83, about five miles S.W. of Louth; (2) that of the minor ridge which stretches from Spilsby to Fulletby. Both these hill-ranges rise to heights of between 300 and 400 feet, but all the rest of the sheet to the southward and eastward consists of low lying ground, much of which (Fen- and Marsh-land) is only 10 or 15 feet above datum-level.

The principal towns in the district are Louth, Alford, Spilsby, Burgh, and part of Wainfleet. Portions of three Roman roads are traceable through it, all starting from Wainfleet (the ancient Vainona). One of these ran westward through Spilsby, Lusby, Winceby, and High Toynton to Horncastle (Bannovallum), the second through Burgh, and along the Wolds through Burwell to Louth and thence probably to Caistor; the third forms part of what is known as the Roman bank, constructed along the seaward edge of the Fenland to protect it from the inroads of the waves; from Wainfleet this road runs by Croft Bank to Skegness, and

thence northward to a point about a mile N.E. of Ingoldmells, beyond which it does not appear to have been carried. All the land east of this bank was exposed to tidal action during the Roman occupation, and has been enclosed since that period.

The drainage of the northern and eastern areas is effected by two principal streams, the Ludd and the Calceby beck, together with several minor streams, flowing eastward off the Chalk Wolds; the south-eastern part of the district is drained by the Steeping river, which rises near Salmonby and falls into the sea near Wainfleet, together with the Hagnaby beck, which rises near Bolingbroke and runs southward into the Catchwater dyke.

Rock Structure. The rocks which enter into the structure of the country included within the limits of Sheet 84 fall naturally into four great groups, each of which is separated from the others by a clearly marked divisional line.

These groups are in descending order:—

4. The Pleistocene.
3. The Upper Cretaceous.
2. The Lower Cretaceous (Neocomian).
1. The Upper Oolite.

The intervals between them were marked by more or less erosion and destruction of the beds previously deposited.

The series commences with the Kimeridge Clay, which is the only member of the Jurassic system that occurs in the district. There are some indications that beds of Portland age once existed, and that they were destroyed during the changes of physical geography which took place before the formation of the Lower Cretaceous beds. These changes included the upheaval of the sea-bottom on which the Kimeridge and Portland beds were deposited, its conversion into dry land which formed part of the great Wealden continent, and its subsequent depression beneath the Lower Cretaceous sea.

The deposits next formed were the three members of the Lower Cretaceous group (see table on p. 3); and the uppermost of these, being a coarse pebbly sand, indicates other geographical changes, which ended in the long continued subsidence of the Upper Cretaceous period. These changes are also implied by the entire absence of any beds comparable to those known as the Gault and Upper Greensand, which in the south of England are found to intervene between the Lower and Upper Cretaceous series.

Of the three divisions of the Chalk, Lower, Middle, and Upper, the two former only are represented in Lincolnshire, the outcrop of the Upper Division lying beneath the sea. The Middle Chalk is therefore the highest member of the secondary series that occurs within the area of the map, and above it there is a great gap and unconformity.

The next group, ("*proximus huic sed longo intervallo,*") is that of the Glacial beds which spread unconformably over all the rest and are found on the highest ground as well as the lowest. They consist of stiff Boulder Clays, with associated beds of gravel and sand.

Lastly come the Post-glacial deposits, certain members of which occupy a considerable area in the south and east of the sheet, forming the low lying tracts known as the East Fen and the Marsh: these are in reality a continuation of the Lincolnshire Fenland. The river deposits are insignificant, and in this respect the country presents a contrast to that on the south side of the Fens.

A tabular view of these rock-groups and their sub-divisions is given below, together with the maximum thickness to which each of them is known to attain.

TABLE OF ROCK-GROUPS IN SHEET 84.

Rock-groups.			Divisions indicated by Colours or Signs on the Map.	Maximum Thickness in Feet.
Pleistocene.	Post-Glacial.	River Deposits	Valley alluvium River gravels	
		Marsh and Fen Deposits	Peat Marsh clay and silt	50
			Blown sand	50
			Beach gravels (Revesby)	20
	Glacial Deposits		Hessle and Purple clays Gravel and sand of above	90
			Chalky Boulder clay Gravel and sand of above	Variable.
Cretaceous.	Upper series		Middle Chalk	200
			Lower Chalk	110
			Red Chalk	12
	Lower series (Neocomian)		Carstone	35
			Tealby Beds (clay, &c.)	100+
			Spilsby Sandstone	40
Jurassic.—Upper series			Kimeridge Clay	100+

Relation between the Form of the Ground and its Geological Structure.

The general dip of the strata in Sheet 84 is to the north-east so that their lines of outcrop strike from S.E. to N.W., and the

oldest beds are to be found in the south-west corner. In consequence of this inclination the various beds above enumerated are brought to the surface in a small area, the highest part of which is not more than 400 feet above the sea, while the thickness of the beds exposed (exclusive of the Post-glacial deposits) amounts to nearly 600 feet.

Again the different formations thus brought to the surface possess different degrees of hardness and stability, so that their capacity of resisting the detritive power of rain, frost, and running water varies very much. It is now a geological canon that the physical features of every country have been determined by the operation of these agencies acting upon the rock surfaces exposed to their influence. North Lincolnshire is no exception to this rule, and indeed few districts bear more unmistakeable signs of having been sculptured out into hill and vale by the action of running water.

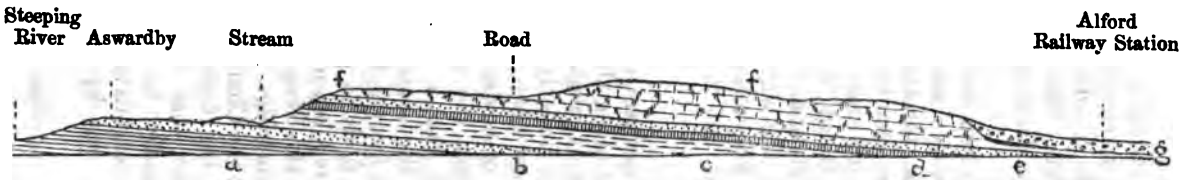
The principal physical feature of this part of Lincolnshire is the escarpment of the Chalk Wolds already mentioned. The edge of this ridge is by no means straight, but is cut back into a number of combes, valleys, and recesses which have been carved out of it by the combined action of springs and rain. Regarded as a whole, however, it faces the south-west, and the general appearance of its outline is shown in Fig. 1, which is a section across it taken along a line drawn from the Steeping Valley near Aswardby on the S.W. to the town of Alford on the N.E. From this it will be seen that anyone walking across the country in this direction will pass over the outcrops of the whole Cretaceous series from basement upwards. Of these beds the Chalk is the hardest and the most capable of resisting the action of rain and running water, consequently it forms the highest ground and presents a bold escarpment to the south-west.

The long valley of the Steeping which intervenes between the Chalk Wolds and the inner ridge has been excavated through the soft Neocomian sands into the equally destructible Kimeridge clay. A glance at the Survey map will show how the Spilsby sandstone has crumbled away under the detritive action of rain aided by the springs thrown out along its base. The edge of the sandstone is fretted out into a series of promontories and outliers, between which open deep and narrow glens or "dales" as they are locally termed. This is especially the case on the south-west side of the Steeping valley where the dip of the beds has favoured this process of erosion.

The structure of the ridge which lies on the south-west side of the Steeping Valley is illustrated by the section, Fig. 2. It may be described as consisting of a platform of Kimeridge Clay, surmounted by a ridge of the Spilsby Sandstone, and flanked on the western side by a sheet of white chalky Boulder Clay. Outliers of the Tealby Clays overlie the sands in some parts of the ridge, and the whole is capped as well as

FIG. 1. *Section across the Chalk Wolds from S.W. to N.E.*

Scale, 1 mile to 1 inch horizontal; 800 feet to 1 inch vertical.

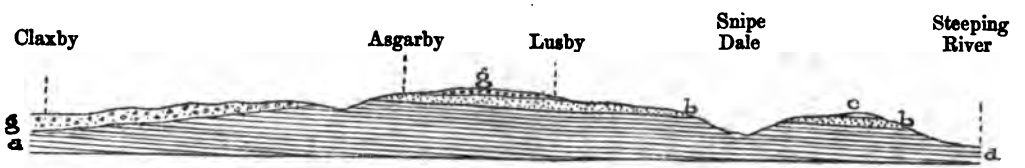


g Glacial beds.
f Chalk.

e Carstone
d Ironstone
c Clay
} Tealby Beds.

b Spilsby Sandstone.
a Kimeridge Clay.

FIG. 2. *Section through the Neocomian range west of Fig.* 1.



g Glacial Beds.
c Tealby Clay.

b Spilsby Sandstone.
a Kimeridge Clay.

flanked by the Boulder Clay, which has once had a much wider extension and has probably been the means of protecting the Lower Cretaceous beds beneath from entire destruction by atmospheric agencies.

From this ridge the ground falls gradually westward to the valley of the Bain in Sheet 83, and more abruptly southward to the broad plain of the Fenland, of which only a small portion comes within the limits of Sheet 84. This Fenland curves round and is continuous with the Marshland which borders the eastern coast.

Between the low lying levels of the Fen and Marsh and the high ground formed by the ridges above mentioned, there is everywhere an intermediate tract or terrace of undulating ground, which is formed by the newer members of the Glacial series, a set of brown Boulder Clays, with some intercalated beds of gravel and sand. The towns of Burgh, Alford, and Louth are situated on this Boulder Clay tract, and the East Lincolnshire Railway is carried along it all the way from Firsby, in Sheet 84, to Grimsby, in Sheet 85. The mean height of this tract above sea-level is about 50 feet, but it slopes gradually down to the Fen and Marsh.

Faults and Flexures.—The most important dislocation in the area to be described is that which runs along the valley between Claxby and Ulceby. Near Claxby it is made evident by the upthrow bringing the Red Chalk and underlying sand to the surface, and it is interesting to note that where these softer beds are present the direction of the valley coincides with that of the main line of fault. It will be seen from the map that this is broken by numerous cross faults, and that the basement beds are also brought up in the valley to the south of Claxby by a branch-fault, which probably joins the former beneath the Drift to the eastward. How far the main fault is prolonged to the south-east there is no evidence to prove, beyond the fact that Chalk was met with in the boring at the Skegness Waterworks (Appendix, p. 168), although there is Kimeridge Clay below Burgh (Appendix, p. 151). This suggests that the Chalk below Skegness is brought in by a prolongation of the fault, a view which receives some confirmation from the fact that the boring passed from Neocomian Clays into what seemed to be Kimeridge Clay, without the intervention of any representative of the Spilsby Sandstone, which may possibly be cut out by the plane of the fault.

Near Driby Grange the existence of another fault is disclosed by the Tealby Beds being brought into apposition with the Grey Chalk. The amount of throw near Driby cannot be less than 80 feet, and there can be little doubt that the line of fault is continued beneath the Drift along the Ormsby Valley. The Chalk north of Ormsby appears to be bent into a synclinal curve, so that the throw of the fault gradually decreases west-

ward, and the base of the Chalk emerges from the north side of the fault near the farm one mile N.W. of Ormsby.

In the valley north of Frog Hall, near Dalby, a line of fault is made visible by the extension of the Red Chalk along one side of the valley only, and it is not unlikely that the small fault at Sutterby (*see* p. 47) is part of the same dislocation.

Between Calceby and Ketsby also the base of the Chalk is brought up by a fault, and the same thing occurs at Withcall, 3½ miles S.W. of Louth.

Nearly every quarry in the Chalk exhibits small slips or faults, and a succession of such faults with throws of a few feet may be seen in the cuttings near Withcall on the Louth and Lincoln line, and by the side of the road in Hubbard's Vale, near Louth. The movements of upheaval and subsidence which the country has experienced since the Cretaceous Period seem to have produced innumerable lines of fracture in the Chalk, and in settling down the beds have become displaced along these lines.

Dips indicating small synclinal and anticlinal curves were observed in several places, but the only one of much importance is the anticlinal, which brings in the long and narrow strip of Kimeridge Clay, near Spilsby; this, indeed, appears to be an elongated periclinal or dome, for the outcrop of the clay is not prolonged through Halton as it would be if the axis were continued in that direction. At the west end also the beds either regain their normal position or are cut off by a fault, the latter being most probable.

The range of the Chalk Wolds is completely cut in two by the valley of the Calceby beck, and it is probable that the portion of this valley which lies to the north-east of the Driby fault coincides with an anticlinal flexure, but the chalk is so broken by small faults that no observed dips can be relied upon, and its lower beds are completely concealed by glacial deposits, so that it is impossible to say how far the outcrop of the basement Red Chalk extends beneath them toward South Thoresby.

Surface Altitudes, or the height of different points in Sheet 84 above Ordnance Datum.

As no heights are marked on the Ordnance Map, the following which I have collected from different sources may be useful:—

Heights in the Marsh.

From the Ordnance Report.

Locality.	Feet above O.D.
Wainfleet Church Tower	15·5
Junction of road to Burgh	8·7
Croft Church Tower	13·2
Junction of roads, Croft Bank	12·6
Ingoldmells Church Tower	10·5
Thorpe Church Tower	10·5
Skegness Church Tower	7·9
Winthorpe Church Tower	10·3
Addlethorpe Church Tower	11·4
Anderby Church Tower	20·2
Hogsthorpe Church Tower	18·2
Mumby Church Tower	18·6
Huttoft Church Tower	37·1
Sutton Church Tower	9·0
West Theddlethorpe Church Tower	11·5

Altitudes along the Louth Canal and through Louth.

Supplied by Mr. T. W. Wallis, C.E., of Louth.

Distance from the Sluice Bridge, Tetney.	Locality.	Feet above O.D.
8 miles	Alvingham	16
9 ,,	Salter Fen	25
10 ,,	Louth Park	38
10½ ,,	Keddington	46
11 ,,	East side of Louth Parish	50
11½ ,,	Top end of canal	56
12¼ ,,	Louth, 146, Eastgate	72
12¾ ,,	St. James Church, Louth	91
13 ,,	West end of Westgate	92
13¼ ,,	Near Thorpe Hall	134

Other Altitudes near Louth.

Supplied by Mr. T. W. Wallis, C.E., of Louth.

Locality.	Feet above O.D.
Waterworks, ¾ mile West of Louth Church	96
Hubbard's Hill, west end	231
Reservoir, N.E. of Hubbard's Hill	225
Railway crossing at Legbourne	78
On road to Elkington, three furlongs from T.P.	190
South Elkington, main road N.E. of Church	378
Kelstern House (in Sheet 83)	390
Main road, ½ mile S.E. of Kelstern	402
Withcall Hill, over the tunnel (Sheet 83)	348

CHAPTER II.

THE KIMERIDGE CLAY.

The lowest and oldest rock found in this part of Lincolnshire is that known as the Kimeridge Clay. It underlies all the eastern portion of the Fen country, and emerges from beneath the fen-deposits and Boulder Clay along the northern border of the Fenland from Tattershall, in Sheet 83, to Halton Holgate, near Spilsby, in Sheet 84. In Cambridgeshire it is very thin, but thickens northward through Lincolnshire, and judging from its superficial extent in Sheets 83 and 84, it cannot here be less than 300 feet in thickness.

The lower part of the Kimeridge Clay is a stiff dark blue clay with numerous layers of large septaria, but its upper portion consists of black shaly clays interstratified with grey papery shales and thin calcareous layers. These shales constitute the Upper Kimeridge of Prof. J. F. Blake; the underlying clays belong to the higher part of his Lower Kimeridge.*

Description of Sections.

The Kimeridge Clay emerges from beneath the gravels and Boulder Clay which conceal it in Sheet 83, and comes to the surface just inside the S.W. corner of Sheet 84, but is at first only exposed along a strip of ground intervening between the Revesby Gravel and the other fen deposits on the south.

"On the east side of the road from Revesby to New Bolingbroke, and about three-quarters of a mile south of Revesby Gate, is an old brickyard, the section of which is stated by the owner (Mr. Skelton) to have been as below:

	feet.
Soil, with a thin layer of sand below - - -	1
Stony clay in which there are pockets of sandy gravel -	3
Stiff blue clay, becoming 'dicey' below - - -	12
	16

"The Kimeridge Clay may also be seen in the roadside ditch along Revesby Bank. Though everywhere along this tract there are hollows

* Quart. Journ. Geol. Soc., vol. xxxi, p. 196.

and pockets filled with sand or gravel and sometimes small depressions filled with peaty matter, the subsoil is clean blue Kimeridge Clay; and at Mr. Scott's farm on Revesby Bank a well was dug 24 feet in such clay and bored about 100 feet further in search of water, but without success.

"The brickyard south of Hagnaby Corner, by the Catchwater drain, discloses Kimeridge Clay at the bottom, but a better exposure is to be found at a brickyard to the southward (within Sheet 69), half a mile W. of Stickney Church. Here 20 or 30 feet of Kimeridge Clay are always exposed, but it has been worked to a depth of about 50 feet, the total depth of the pit being then 60 feet. A layer of large septarian nodules was met with about 40 feet from the surface; a heap of these lay near the pit, and most of them contained large smooth Ammonites."*

The Jurassic Clay is exposed in the broad valley in which Old Bolingbroke is situated; this hollow has clearly been excavated by the combined action of the numerous little streams which issue from the springs thrown out at the base of the Spilsby Sandstone. These watercourses have produced deep dales which penetrate the high ground to the northward and eastward, and in some of which the upper shaly portion of the Kimeridge Clay may be seen. Some of these shales are black and bituminous, and their occurrence leading the inhabitants to suppose there was coal beneath, a trial shaft was sunk many years ago to the depth of about 600 feet, but I could not obtain any particulars of the sinking.

The Kimeridge Clay skirts the high ground formed by the Neocomian beds between Bolingbroke and Spilsby; it sweeps round the flank of Hall Hill, and occupies the slopes below West Keal Church; fossils are found from time to time in draining these slopes, vertebræ of *Ichthyosaurus* and teeth and vertebræ of *Plesiosaurus* are in the possession of Colonel V. Grantham, of Keal Hall.

Where the road ascends the hill between West and East Keal, blackish clay with septaria is seen in the bank below an old sand pit. At the spring head two furlongs S. of East Keal Vicarage 3 or 4 feet of sand were seen overlying wet dark blue clay with septaria, but its outcrop to the southward is concealed by the superimposed drift deposits. I was informed by a well sinker (Mr. Chester) of East Keal that he had sunk several wells in the lower part of the village, finding water in a bed of black shale about 20 feet down; he stated that this material would burn almost like coal, it is evidently the same bed as that found near Bolingbroke.

Dark-coloured shaly clay is visible (below loamy sand) where the watercourse from Keal Carr opens out the Boulder Clay plain. There is an old clay pit (now grown over) by the laneside 5 furlongs N.E. of Toynton All Saints, and the clay here is said to have contained many bones. Its extension westward through Halton Holgate is very obscure, for it is covered with a loamy soil, and the boundary line of the overlying sandstone is not at all easy to trace. Northward the beds appear to rise into a low anticlinal; and this has been so denuded that the Kimeridge Clay is exposed in a slight depression which forms an inlier and traverses the whole length of the ridge on which the town of Spilsby is built. Dark clay is found in the hollow N.W. of Halton Holgate, and half a mile W.N.W of the church is an old pit whence clay was obtained 30 years ago for making bricks; blue clay with a few small phosphate nodules can still be seen, covered with a brown clayey loam, but the width of the exposure is only about two hundred yards, and the sandstone is shown in a sand hole between the old pit and the road. The strip of clayey soil can be traced westward between Spilsby and the railway, and wells have been sunk into the clay for a depth of 90 feet in search of water but of course without success. The anticlinal can be followed as far as Hundleby, where it appears to be cut off by a north and south fault.

Eastward and northward the Kimeridge Clay crops out along the banks

* These paragraphs are taken from the Memoir on Sheet 70, pp. 72, 73.

of the river Steeping, and the following section was observed half a mile S.S.W. of Ashby Church :—

	ft.	in.
Sandy wash	6	0
Dark blue clay (partly hidden)	5	0
Grey papery shales	0	3
Black shaly clay	1	0
Grey papery shale, crushed shells	0	1
Dark grayish brown clay	1	0
Hard gray band (? calcareous)	0	2
Dark blue clay (lumpy, with septaria)	3	0
	16	6

From these shales the fossil collector (Mr. Rhodes) obtained *Discina latissima*; *Lingula ovalis*, *Astarte*, sp., *Ammonites* (impression), and a hooklet of Cuttlefish.

Its extension to the eastward is concealed by Boulder Clay, but westward to and beyond Partney the Jurassic Clay is exposed along the lower slopes of the Steeping Valley for a considerable distance. There is a large clay-pit 5 furlongs eastward of Partney Church, where many fossils have been found, but this is now overgrown and full of water.

In the bank of a large pond half a mile N.W. of Hundleby Church, the outcrop of the gray papery shales is seen, and similar gray and black shales are visible in the side of the beck 2½ furlongs N.E. of Raithby Church; above these and below the pond whence the stream issues lumpy bluish-black clay is exposed. Clay with septaria and a few dark phosphate nodules is seen in an excavation about six furlongs N.E. of Raithby. Similar sections occur here and there in the deep valleys north of Mavis Enderby and south of Hagworthingham.

Dark clay with septaria is seen in a pit ¼ mile S.W. of Sausthorpe Church. A better section, however, is to be found in a deeper pit about three furlongs N.W. of the same church; here the following beds are visible :—

	feet.
Sand with nodule bed at the base	0 to 3
Blue shaly clay	3
Black papery shales	2
Hard calcareous band (compare the section at Ashby)	0½
Dark blue clay about	10
about	18

The Kimeridge Clay continues on either side of the river below Harrington, Enderby, Somersby, and Salmonby, and is traceable for a little distance up the valleys of the brooks which descend from the high ground west of Salmonby, before it passes beneath the overlying sandstone.

The only good exposure here is in a pit by the side of the beck two furlongs N.W. of Salmonby Church, showing :—

	feet.
Sandy wash from above	3
Dark bluish-gray clay	5
Drab-coloured shales, with impressions of bivalves, *Lingula ovalis*, &c.	1
Continuous layer of septarian stone	0½
Dark blue clay	1

West of the Fulletby Hills there are two or three small areas where the Kimeridge Clay emerges from beneath the great sheet of Boulder Clay which spreads over this part of the county. In one of these about a mile west of Fulletby there is a brickyard showing some 15 feet of papery shales,

with a band of large calcareous doggers near the top. Prof. Blake remarks of this locality that the shales are crowded with the white compressed shells of *Discina latissima* and *Lucina minuscula*: he obtained the following fossils here:—*

Ammonites biplex, Sby.
Aptychus biplex.
Belemnoteuthis.
Trochus retrorsus, Blake.
Dentalium Quenstedti, Blake.
Lucina minuscula, Blake.
Astarte lineata, Sby.
Pecten lens, Sby.
Cardium striatulum, Sby.
Avicula vellicata, Blake.
Gervillia tetragona, Röm.
Ostrea gibbosa, Les.
Discina latissima, Sby.

* Quart. Journ. Geol. Soc., vol. xxxi., p. 201.

CHAPTER III.

LOWER CRETACEOUS (NEOCOMIAN).

The Lower Cretaceous or so called Neocomian beds of Lincolnshire are the homotaxial representatives of the Wealden and Lower Greensand series of southern England; that is to say, they occupy the same position in the serial order of deposits, but they were deposited in a distinct area of accumulation and under different physical conditions, so that they present a very different facies from that developed in the southern counties.

In the first place there are no fluviatile deposits at their base comparable to the Wealden beds; they are wholly marine and their basement bed consists of materials derived from the destruction of older rocks. There is here, therefore, a great break in the geological record, and the exact epoch at which deposition again commenced is consequently uncertain.

Professor Judd has shown that the Lower Cretaceous beds of Yorkshire and Lincolnshire are the most westerly portion of a great mass of strata which stretch over a wide area in northern Europe.* He remarks also that the members of this group everywhere maintain a remarkable uniformity of character, indicating that the North-European district forms a natural province or basin of deposition; and that this Anglo-Germanic basin was probably separated from the southern or Anglo-Parisian basin by an intervening ridge of land.

Professor Judd found that the group of beds in Yorkshire, for which he adopted the Swiss name of Neocomian, were naturally divisible into three sub-groups or stages, which he termed Lower, Middle, and Upper. I feel constrained to use the same nomenclature in this memoir, though I think the use of the word Neocomian is to be regretted on two considerations; (1.) It is consistently used on the Continent to designate the Lower only of these three stages. (2.) It is part of the nomenclature of the southern basin of deposition, with the strata of which those of the northern basin have not yet been accurately correlated. To obviate the confusion which now exists a new name is required, either for the upper portion of the British series, or for the Anglo-Germanic group as a whole.

Further, although the Lincolnshire series is also naturally divisible into three stages, it is by no means certain that they correspond respectively with the Lower, Middle, and Upper stages of the Speeton Clay. The following is a general section

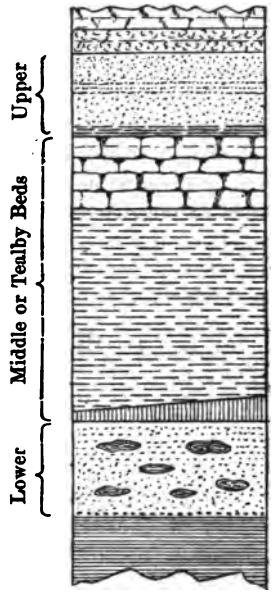
* Quart. Journ. Geol. Soc., vol. xxiii., p. 227; xxiv., p. 214; xxvi., p. 326.

of the succession to be met with in the southern part of Sheet 84 :—

FIG. 3.

Vertical Section of the Neocomian Series.

Scale 80 feet to an inch.



The nodule bed at the base contains rolled casts of fossils, which appear to have been derived chiefly from beds of Portlandian and Kimeridge Clay. It is not unlikely that this bed is a continuation of the nodule bed which occupies a similar position at Speeton, but which Professor Judd seems to regard as actual Portlandian; in Lincolnshire, however, there can be no question about the stratigraphical position of the bed or the rolled and transported nature of its fossil contents.

The fossils in the sandstone above are a somewhat peculiar assemblage; but if they correspond to any part of the Speeton Clay it would seem to be the lowest part of the Lower Stage; their lithological character being so different it is not to be expected that they should contain many of the same species, and so instead of *Ammonites noricus* and *Am. astierianus*, we find *Am. plicomphalus* to be the prevalent and characteristic species in the Lincolnshire sandstone. As this occupies a considerable area near Spilsby we propose to term it the Spilsby Sandstone.

The Tealby Beds were correlated by Professor Judd with the Middle division of the Yorkshire series; but if any faith can be placed in Ammonites the Lower half of the Tealby Beds must

be referred to the zone of *Am. speetonensis*, for that species has been found everywhere in the lower blue clays. At the same time *Pecten cinctus* occurs both in the lower and the upper ironstone associated with these clays.

The Upper Sand or Carstone has not yielded any fossils, except at its junction with the overlying Red Chalk, where *Terebratula biplicata* occurs. There is nothing to show that it is represented at Speeton, and Mr. Strahan and I are inclined to refer it to a higher horizon than any part of the Speeton Clay. It is presumably of the same age as the Upper Carstone of Norfolk, and may be the equivalent of the highest sands (Carstone) in the Wealden area.*

The names above given to the three divisions of the Lincolnshire series have been agreed upon by Mr. Strahan and myself; taking these divisions in their natural order I shall describe the stratigraphy of each within the limits of Sheet 84.

§ 1. Spilsby Sandstone.

At the very base of this division and resting directly on the Kimeridge Clay, there is always a thin seam of derived phosphatic nodules and casts of fossils, similar to those of Potton and Sandy in Bedfordshire.

The mass of the rock above consists of greenish-yellow sand, which is in many parts compacted into a soft sandstone. When quarried the stone is very soft and friable, but hardens on exposure to the air, so that it is capable of being used as a building-stone, and nearly all the old churches in this part of Lincolnshire are built of it. In some places there are thin courses of brown ferruginous sand enclosing arenaceo-phosphatic nodules. Large boulder-like concretions of hard calcareous sandstone are also of frequent occurrence.

Occasionally, as near Spilsby, it is overlain by ironstone, but elsewhere the sandstone passes into soft yellow loams and sands, which graduate into the yellow loams and clays at the base of the Middle Neocomian or Tealby series. This division appears to become much thinner towards the south-east, only 19 feet of sand being found beneath the Tealby clays in the deep boring at Skegness (*see* Appendix p. 168). It is possible, however, that this boring intersected the inclined plane of a fault and that part of the Sandstone was thus cut out.

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* I believe that the Carstone and the Tealby beds are not Neocomian in the continental use of the term. I have discussed this use in Geol. Mag. dec iii., vol. iii., pp. 311, 431, 1886 (*see* p. 382 of that vol. for Professor Judd's reply). The relations of the Carstone of Lincolnshire have been discussed by Mr. Strahan (Quart. Journ. Geol. Soc., vol. xliii., p. 486, 1886). He considers the Carstone to be largely made up of material from the Tealby beds and Spilsby Sandstone, and believes that the most important break in the Lincolnshire Cretaceous series occurs at the base of the Carstone. In this view, however, I cannot concur.

This sandstone occupies a far larger area than either of the other divisions: it everywhere forms a tract of light sandy soil between the heavy clays below and above. Before the Glacial period it seems to have formed a broad plateau, stretching out from the base of the great chalk escarpment and forming a second smaller escarpment of its own at a distance of some 3 or 4 miles to the westward. This sandstone escarpment is partially concealed by the mantle of Boulder Clay which was spread over it, but has been exposed here and there by Post-glacial denudation. The plateau itself is deeply trenched by the valley of the Steeping River, which appears to have been wholly excavated in Post-glacial times, so that the outer portion forms a long peninsula, capped here and there by outliers of the Tealby Series, and only united to the inner portion by the narrow neck near Fulletby. In describing the exposures of this division it will be convenient to commence with the neighbourhood of Spilsby and to follow the tract of sandstone round the head of the Steeping Valley.

Description of Sections.

The road-cutting east of Halton Holgate exposes beds of greenish-yellow sandstone, sufficiently compacted to form a vertical face, but crumbling beneath the hammer; diagonal lamination is observable in places, near the surface and under roots the rock acquires a rich brown tinge from the oxidization of the iron, and the resulting soil is a loose brown sandy loam often 4 or 5 feet deep.

The same compacted sand or soft sandstone is exposed in the road-cutting west of the village, where it has been quarried for a depth of about 12 feet. The wells in the village are said to be about 20 feet deep, finding the base of the sand.

Five furlongs north of Halton Church there is a small sand pit showing about 8 feet of greyish white sand, containing three concretionary masses which are hard in the centre and are full of *Pecten orbicularis*. Round these nuclei are concentric circles of colour which doubtless indicate the original size of the calcareous concretions, the passage of water having destroyed them by carrying away the carbonate of lime in solution and depositing oxide of iron. Close by a spring issues from the sand which is stained of a rusty yellow colour by the iron.

At Spilsby, when the foundations for the new Methodist Chapel were excavated (1877), the section exposed was—

	feet.
Brown sandy soil	4½
Hard nodular ferruginous beds with arenaceo-phosphatic nodules	0½
Yellowish-brown sand	2

Besides the nodules hard rocky lumps occurred on the same horizon, containing *Belemnites lateralis*, *Pecten orbicularis*, *Pleurotomaria*, *Perna*, and other fossils.

The same beds are visible below a hedge on the west side of the road half a mile N.N.E. of the church, the succession here being—

	feet.
Brown sand and sandstone	1
Coarse brown sand with phosphate nodules and hard ferruginous lumps	0½
Greenish sandstone, seen also in the road-cutting near by	2

West of this road is a deep carr or valley resulting from the outburst of strong springs near the base of the sand, and west of this again (about 3 furlongs N. of Spilsby Church) there is a sand pit showing 6 feet of greenish yellow sand, compact below with occasional hard lumps of hard brown sandstone, but becoming softer above and passing into a loose brown soil. Similar beds are seen in the road-cutting to the north (Blue Hill).

No sections of the sandstone were seen by Hundleby or Raithby, but along the boundary line in the hollow, about half a mile N.E. of Raithby Church, numerous phosphate nodules were found scattered about on the surface, though the actual outcrop of the seam was not perceived.

At a spot about 6 furlongs N.N.E. of Raithby there is a small clay pit which shows the junction of the two formations. At the top of the bank there is from 1 to 2 feet of greyish green sand passing down into dark green sand mixed with clay, and containing many phosphate nodules; below this there is dark clay, the upper part of which appeared also to contain a few similar nodules, and lower down large septarian concretions were plentiful.

The nodule bed could be traced across the fields to the S.W., and the phosphates seemed often to lie in patches, as if they occurred in hollows of the clay.

Myacites recurva? was the most abundant fossil, but casts of *Lucina portlandica, Ammonites biplex,* and *Trigonia* also occurred. Nodules were also found at the top of a similar pit half a mile N. of Mavis Enderby.

South of Spilsby by Eresby Hall the sandstone spreads over a considerable area, and a good section of it is exposed in a large pit 3 furlongs S.E. of the Hall, viz., some 10 to 15 feet of compact yellowish-brown sand containing large boulder-like masses of hard calcareous ragstone. These concretionary masses are full of fossils, *Ammonites plicomphalus* and *Pecten orbicularis* being the most abundant; the stone, when broken, somewhat resembles Kentish Rag, and makes excellent material for road mending.

The same beds with masses of hard ragstone are seen in the sand holes 2 furlongs W. of Toynton All Saints; many fossils were obtained here. For list, see Appendix, p. 140.

On the other side the valley and N.E. of East Keal Church there is a deep carr, in the side of which are exposed several feet of greenish sandstone, weathering brown, with 8 or 10 feet of soft yellowish-grey sand below. At the road corner, one furlong W. of the church, is a small pit in sand with large ragstones like those above-mentioned; above this part of the sand there is a thin layer, containing arenaceo-phosphatic nodules like those at Spilsby. The wells in the village are from 30 to 40 feet deep, finding a plentiful supply of water at the base of the sand. The next exposure is in a small pit on the N. side of the road 2½ furlongs E.S.E. of West Keal Church, but a better section is to be found near the farm half a mile N.W. of this church; near the entrance to this a thin layer, containing small nodules, fossils, and pieces of carbonized wood is observable. The deepest excavation shows about 12 feet of yellowish-brown sand, which hardens into a soft sandstone by exposure; many large ragstones are dug out here and broken up for road material; they yield numerous fossils, *Pecten, Trigonia, Ammonites,* &c. (see list p. 140).

The basement bed with phosphatic nodules was observed in the hollow south of East Keal, and many nodules and casts of fossils in black phosphate were found on the surface below the slope of sandstone.

The lower portion of the sandstone is cut through in the road-cutting north-east of Bolingbroke, and the basement beds with phosphatic nodules here and there may be followed along the slopes of the beautiful valley known as Sow (? South) Dale.

By the road to Asgarby, about three-quarters of a mile N.W. of Bolingbroke, is a sand pit dug in soft yellowish and white sands which contain large concretionary masses like those at Toynton and elsewhere; they are yellow or brown outside, but greenish inside, and may be described as masses of hard calcareous grit or ragstone; they contain *Ammonites* and *Pecten orbicularis* as elsewhere.

Mr. Strahan has furnished me with the following notes on sections observed in the area surveyed by him :—

"A sand pit near Asgarby, on the road to Bolingbroke, shows 8 to 10 feet of soft buff coloured current-bedded sand, containing concretionary lumps of sandstone, grey and brown, and about 2 feet in diameter.

"About 250 yards S.S.W. of Asgarby Church a pond was being excavated in soft green sand full of water, apparently within a foot or two of the junction of the Neocomian and Kimeridge Clay. The hill side below this junction is composed of a strong blue Kimeridge Clay soil with numerous phosphatic nodules, which have been washed down from the base of the Spilsby Sandstone."

"Between Winceby and Lusby a quarry has been opened in the Spilsby Sandstone. The lumps of rock are larger there than in the pits about Asgarby, and further north predominate over the incoherent sand; about Holbeck and Salmonby the greater part of the subdivision is in the coherent rocky form, with a brown colour. West of Fulletby it loses this property and becomes a soft white sand with little rock. Where it occurs in the rocky form, as at Holbeck, it is usually cut into a number of small picturesque ravines by the numerous springs which issue from its base and make their way eastwards to join the Steeping. These springs are occasionally ferruginous.

"The junction of the Sandstone and the Kimeridge Clay is everywhere concealed by the washing down of the sand. It appears, however, that the sand is slightly unconformable to the clay. The former usually contains near its base a number of rolled phosphatised casts of Kimeridge Clay fossils, derived without doubt from the erosion of the upper beds of the Kimeridge Clay. These phosphates may be picked up in almost any freshly ploughed field or in the soil along and just below the junction. Further to the north (about Brigg, Sheet 86) the overlap of the Kimeridge Clay by the Neocomian becomes more obvious. In the present district, however, it is not sufficiently rapid to be detected in the mapping of the lines."

A. Strahan.

At Salmonby, close to the church, there are old quarries whence the stone has been obtained for building purposes; and another more recent quarry by the side of the road to Somersby, about three-quarters of a mile from the former. The stone here lies in massive beds 3 or 4 feet thick, with very few joints, and may therefore be called a freestone; in colour it is yellowish-grey, weathering greenish on the vertical face, but forming a reddish-brown sandy soil. The face of the pit is about 16 feet deep.

In the gully above the Holy-well N.W. of Somersby, several feet of yellowish and greenish-brown sandstone are visible; the spring itself being of course thrown out at their junction with the Kimeridge Clay below. The basement bed, full of phosphate nodules, may be seen in the roadside ditches near the junction of the roads from Ashby and Somersby.

At Harrington Carr there are old quarries in the same green and brown sandstone, but towards Aswardby the rock seems to become softer and looser, as seen in the sand pit about 300 yards N.W. of Aswardby Church. Phosphate nodules are plentiful in the fields between the main outcrop and the outlier west of Aswardby.

Round Sausthorpe this division occupies a considerable area. A depth of 30 feet was found at a house about two furlongs N.E. of the church, so that its total thickness here must be between 40 and 50 feet. The passage from these sands into the Tealby Clays may be seen by following Langton Carr northward from the church, or in the ditch running by the farm half a mile S.E. of Langton. In the latter the ascending succession is (1) soft yellow loam, (2) loamy sand, (3) loamy clay passing up into yellow and grey mottled clays where the cart-track crosses the streamlet.

The basement-bed with phosphates is also well exposed at the top of a clay-pit three furlongs N.E. of Sausthorpe. Here the Kimeridge Clay is surmounted by about 2 feet of sandy soil, containing a quantity of the

nodules and casts of fossils; but the bed had the appearance of being a wash from the slope above, and not the actual outcrop of the seam itself. For fossils, see Appendix, p. 139.

By the farm, half a mile N.W. of Partney, there is a small pit showing 6 or 7 feet of yellowish-green sand, just sufficiently compacted to stand with a vertical face, but easily dug with a spade. Through these sands the brook has cut a narrow channel or "carr" for itself west of the village, and they can be traced for a little distance eastward before they are overlapped by the sheet of Boulder Clay which sweeps round the southern termination of the Chalk Wolds and conceals the outcrop of this lower sandstone eastward of Partney.

There are two places, however, where the Neocomian sand appears to form hillocks round which the glacial clay is bedded. One of these is a hill between Partney and Ashby, which consists of sand, and on the southern slopes of which springs are thrown out. Again, in Ashby Field, about half a mile N.E. of Halton Bridge, soft yellowish sandstone is exposed in a pit by the roadside. This is probably an outlier.

§ 2. The Tealby Beds.

This name was proposed by Professor Judd for the middle division of the Neocomian series in Lincolnshire, on account of the prominent feature it makes between Tealby and Caistor. It is a variable series of clays and ironstones with a band of limestone near Tealby which, however, thins out entirely to the southward. In Sheet 84, the succession is as follows:—

3. The "roach," a soft yellow ferruginous marl, containing oolitic grains of iron; this occasionally passes into a hard ironstone rock; thickness from 20 to 40 feet.
2. Blue clays with selenite and small septarian nodules. These are 70 or 80 feet thick near Dalby, and seem to become still thicker beneath the Chalk to the south-east. (See borings in Appendix pp. 151 and 168).
1. Yellow loam with occasional beds of oolitic ironstone of variable thickness and quality, resting on the Spilsby sandstone.

The clays form the lower slopes of the Cretaceous escarpment, and where the roach contains layers of hard ironstone, these produce a marked feature, forming a terrace or platform with bold promontories, below the higher slope which is surmounted by the Lower Chalk; where the roach is soft this terrace is less prominent, but is still a noticeable feature in the landscape.

Main Outcrop.

This division is first seen at the village of Candlesby, where it emerges from beneath the Boulder Clay, and forms the ridge on which the village is built; it is not exposed by any section, but appears to consist of two members, the lower being blue clay and the upper a soft oolitic ironstone. At the Inn a well was dug about 25 feet through marl and roach into sand.

At Scremby an excavation in a garden, one furlong N.N.E. of the church, showed about 6 feet of yellow marly clay with bands of the calcareous and oolitic ironstone which is locally called "roach." It is here softer than usual, and would be called "clunch" in Cambridgeshire. It is stated that below this there is a red sand from which water is obtained.

At the farm two furlongs N. of church the well is said to be 40 feet deep through roach to sand, and as the Upper Sandstone comes on immediately above, this depth may be taken as the measure of the roach.

The outcrop of these ironstone beds forms a broad platform to the west of Scremby, with bold knolls along its southern edge, below which lies the slope formed by the underlying yellow and blue clays. The dark brown soil formed by the ironstone is well seen on the hill which lies to the west of the road to Grebby Hall, and lumps of the ironstone beds have been turned out of the pond by the farmstead at Grebby.

Thence it is traceable to the N.W. till it is cut off by the little fault south of Skendleby and its outcrop shifted westward under the Boulder Clay which runs up the valley. It is seen again, however, below the spring two furlongs west of Skendleby Lodge where the trench, cut for the passage of the water, shows 5 or 6 feet of brown shaly sandstone, with bands of harder dark brown oolitic ironstone; the specimen, an analysis of which is given on p. 134, was taken from one of these.

Higher up this valley and on the south side of the stream between Fotherington and Dexthorpe the blue clays of the Neocomian are exposed in the road cutting, and the thickness of ironstone above must be very small indeed, as the Carstone and the Red Rock come on almost immediately. The roach or ironstone division is a very variable stratum, and its thickness is probably as variable as its lithological composition.

West of Skendleby Thorpe the soft roach beds make a definite feature, but they appear to thin out when traced northward upon the next valley in the direction of the last-mentioned locality.

About Dalby there is a wider expansion of the Middle Neocomian. Yellow clay is found round the base of Dalby Hill, passing up into blue clay, and capped by an outlier of the ironstones. The well at Beverley Farm, near that marked Red House on the map, is said to be 50 feet deep in clay without reaching the bottom or obtaining water. The total thickness of the clay cannot be far short of 80 feet. In Dalby Park there is a spring rising from the ironstone about two furlongs S.S.E. of the church; the valley south of the Hall is cut out of the blue clay, and ditches on the north side show that this passes up into yellow loamy clay with bands of "roach" and rubbly ironstone. Springs are thrown out above these, at the base probably of the more arenaceous portion of the ironstone series (as seen on the south side of the valley).

From Dalby the clays continue to form the lower slopes below the escarpment, from which they are separated by the platform of the ironstone beds.

In the valley east of Langton the Spilsby Sandstone passes up into yellow loam and loamy clay; about the middle of the slope are old pits, whence blue clay was obtained for making the bricks used in the construction of Langton Hall.

The Hall itself stands on the ironstone, and masses of this rock may be seen in the rockery. These were said to have been soft and crumbling when excavated, but hardened on exposure: a well was sunk through the soft ironstone for 12 feet, at which depth a hard rock was met with. The ironstone here has yielded *Pecten cinctus* and *Exogyra sinuata*.

N.W. of Langton Hall the ironstone forms a bold knoll with perhaps a capping of sand; its outcrop then trends northward to Sutterby, following the line of the Chalk escarpment, while the clay below spreads out over a wider area towards Harrington and sweeps round the base of Harrington Hill to Brinkhill, in which neighbourhood aggregated crystals of iron-pyrites frequently occur in the clay, and are locally known by the name of Brinkhill Gold. The outer spurs of Harrington Hill are formed by the roach and ironstone, and a bed of the latter crosses the road half a mile S.S.W. of Brinkhill Church.

North of Brinkhill the Neocomian Clay is concealed by a covering of gravel and Boulder Clay, but its upper edge can be traced to the N.E. till it is cut off by the Driby Valley fault; the yellow clays with ironstones extend up this valley on the S.E. side as far as Driby Grange.

Cloven Hill, Warden Hill, and Ormsby Hill are outliers of Chalk and Upper Neocomian, resting upon a platform of the ironstone, which is in turn surrounded by slopes of Neocomian Clay. The only section worth noting is that at the brickyard on the road to Tetford, N. of Warden Hill.

The clay here is yellowish near the surface, but blue below. It contains many crystals of selenite and calcareous septaria of various sizes, some of which enclose crustacean remains.

The following succession was observed at the N.E. corner:—

	Feet.
3. Stiff yellow clay passing down into	2
2. Stiff blue clay	10
1. Soft yellowish shaly loam	3

This is possibly its base and junction with the Lower Neocomian.

Mr. Strahan has supplied me with the following notes upon the Tealby Beds lying to the north and west of the tract already described:—

"In the rising ground west of Salmonby, Ashby Puerorum, and Hagworthingham the Spilsby Sandstone passes nearly horizontally under the Tealby Clay. The latter is exposed in a narrow fringe appearing from under the Boulder Clay between Winceby and Greetham, and further north occupying a broad spread about Belchford. It forms a stiff clay soil of a yellow or (where freshly exposed) of a pale blue colour. At the junction of this clay with the underlying sandstone there occurs in places a bed of calcareous stone with numerous oolitic grains of iron oxide scattered throughout it. I saw fragments of this bed thrown out of a field-drain in the head of the valley three-quarters of a mile south-south-east of Greetham; and in many other places along the outcrop the soil may be seen to be crowded with the small black oolitic grains. The bed is on the same horizon as, and probably continuous with, that which is worked for commercial purposes at Claxby (Sheet 86). There are no pits in the overlying clay, and fossil collecting is consequently difficult. Fragments of *Exogyra sinuata* (?), which is exceedingly abundant in the same clay further north, may occasionally be picked up.

The upper division of the Tealby Beds is constituted by a very impure ferruginous limestone. It emerges from beneath the Boulder Clay near Fulletby, and forms a more or less level plateau on the top of the hill extending northwards from this village. A small but very conspicuous outlier occurs on Hoe Hill; the regular feature produced by the superposition of the rock on the soft clay gives the hill an appearance of having been artificially entrenched. The outlier is about 150 yards long and from 30 to 40 yards broad, and is therefore about the size as well as the shape of a British camp. The form of the ground is, however, attributable to natural causes.

In another outlier north of Belchford this rock forms a similar shelf, very distinct on the south-east and north-west side; on the south-west side is a smaller scarcely detached outlier. A steep-sided ridge of Carstone and Red Chalk and a narrow strip of White Chalk rests on the larger of the outliers; but are a good deal disturbed by slipping.

The characteristic feature of this rock is again seen in an outlier 1½ miles north-west of Belchford, all the western part of which, however, is overspread by Boulder Clay.

In the Chalk escarpment the outcrop of this rock is well marked about Tetford Parsonage and in Belchford Hill, but northwards its position is inferred only from the nature of the soil, which is composed of soft roach, with oolitic grains of iron oxide. This roach runs round Gaumer Hill and northwards along the escarpment towards Cawkwell (Sheet 83). In no part of the hill does the calcareous rock which makes so conspicuous a feature about Fulletby appear. On Gaumer Hill the principal feature is made by the Carstone.

About Salmonby and Ashby the beds are nearly horizontal, but south-west of Belchford the dip towards the chalk to the north-east is clearly perceptible on following the lines across the ground, and is probably not less than 3° or 4°.

The ferruginous limestone of Fulletby is probably the same limestone as that described by Prof. Judd* in the district lying from 5 to 20 miles further north. As before stated, the Fulletby Rock does not appear as a clearly distinct lithological subdivision north of the Belchford outliers and the adjoining parts of the escarpment. But in Sheet 83, about three miles only from where the Fulletby Rock dies out, loose blocks of an impure limestone are found in the soil along the same line of outcrop. These become more abundant northwards, until finally near Hainton and Sixhills the rock appears in solid beds, which have been quarried in several places. This Tealby Limestone and the Fulletby Rock are therefore upon the same horizon, and, though not precisely similar in character, may be regarded as equivalent deposits in the north and south respectively.

A. STRAHAN.

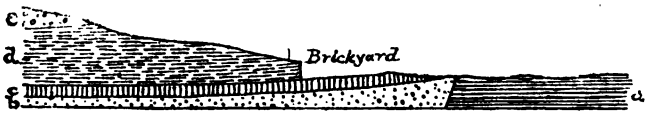
Outliers.

The hill south of Raithby and west of Spilsby consists of Tealby Clay, capped by some thickness of Chalky Boulder Clay; the former can be traced along the hill-flank as a narrow strip of dark clay soil between the white clay above and the soft brown sands below. Stiff blue clay is seen by the side of the road down its eastern slope, and the base of the clay is exposed in the brickyard S.W. of Hundleby, where the word "kiln" is engraved on the map.

About 18 feet of clay is seen in the more southerly part of the yard, the lower 10 feet being stiff blue clay with septaria passing up into grey and purple laminated clays, with yellow loamy clay at the top. These clays rest on a floor of hard calcareo-ferruginous rock, full of brown oolitic grains like the Tealby ironstone, and of a bluish-grey colour inside, but weathering to a yellowish brown; the well at the cottage has been dug to a depth of 14 feet without piercing it. The fossil collector (Mr. Rhodes) obtained some fossils from the ironstone which are given in the Appendix, p. 141. This rocky floor undulates considerably, a ridge of it comes up suddenly near the kiln, and thence it slopes both southward and northward; but, according to the foreman, it quickly rises again in the latter direction, and forms an anticlinal ridge, coming so near the surface that between the two kilns there is hardly any clay above it. This may represent the dying out of the anticlinal axis which brings up the tract of Kimeridge Clay to the eastward, but the space between its outcrop and that of the Kimeridge Clay is so narrow that there is no room for the breadth of sandstone that should intervene between them, and we are compelled therefore to suppose that the latter is brought up by a fault cutting across the anticlinal from north to south. Fig. 4 explains the arrangement of the beds on this view.

FIG. 4.

Section across Hundleby Brickyard.



e Boulder Clay.
d Tealby Clay.
c Ironstone.
b Spilsby Sandstone.
a Kimeridge Clay.

A strip of dark clay is traceable westward along the southern flank of the hill, and across the road leading to West Keal; west of this road and

* Quart. Journ. Geol. Soc., vol. xxiv., p. 244.

about two furlongs S.E. of Mavis Enderly is an old brickyard which has not been worked for many years and is much overgrown, but loamy grey clay, banded with yellow, can be distinguished in the bank. This ridge of clay extends still farther westward, but is partially concealed beneath another outlier of Boulder Clay.

Marden Hill, near East Keal, is formed by another outlier of Neocomian Clay, capped likewise by a patch of chalky Boulder Clay (see section, p. 83). There is a brickyard on the north side of the hill, where about 20 feet of blue shaly clay is exposed with 6 to 8 feet yellow loamy clay above it, yellow and grey bands occurring where these pass into one another, and in the yellow loam there are thin layers of ferruginous sandstone.

In the lower part of the blue clay flattish lumps of iron pyrites are common, and when broken exhibit numerous minute holes which appear to have been originally occupied by oolitic grains; many of these lumps contain remains of woody structure. The fossils obtained from the base of the clay will be found in the Appendix, p. 142.

The floor of the pit is said to be on a hard rock, which is probably the same bed as that seen at Hundleby. The beds appear to have a slight inclination to the S. or S.E., and this is confirmed by the occurrence of a strong spring on the eastern flank of the hill which issues from an ironstone rock above the clay, like that in Dalby Park; the exposed area of this rock seems very small for the production of a spring, for it passes under the Boulder Clay to the westward.

Round Hagworthingham there are several small outliers, and nearly a mile E.S.E. of the church there is an old brickyard exposing blue clay with a thin band of decomposed oolite ironstone.

Inliers.

At Skendleby Salter, a farm in the valley between Ulceby and Claxby, the Tealby series is just exposed in the sides of the pond below the house; brownish clay with a layer of hard ironstone rock being visible at one corner, and many fragments of the ironstone occur round the pond. A boring was made here for more than 100 feet without reaching the base of the clays, and the only water obtained trickles in from some of the ironstone beds near the top (see Appendix, p. 168). Similar beds were met with in a well half a mile south-east of the above.

The only other inlier is the remarkable one in which the village of Oxcombe is situated, and which extends eastward by Farforth and Ruckland to within a mile of Walmsgate. The roach beds make a decided feature round the western portion of this inlier, especially near Oxcombe, and lumps of the soft oolitic roach were found in the gardens at Oxcombe Hall, but no good exposures were seen either in this or the underlying clays.

The Carstone.

This division consists of coarse yellow and brown sands, the grains being chiefly quartz and "lydian stone." It is generally loose enough to be dug with a spade, and is seldom sufficiently compacted to be called a sandstone. Its upper beds frequently contain broken and rolled phosphatic nodules which have evidently been derived from older deposits. Its thickness appears to vary from 20 to 40 feet, and its outcrop forms a steep slope, often wooded, below the red rock or basement bed of the Chalk.

Springs are often thrown out at its base, and have assisted those from the Red Rock in forming the numerous little hollows and valleys which indent the outline of the great escarpment.

No fossils have yet been found in it, except quite at the top, where it appears to pass into the Red Chalk. *Terebratula biplicata* and *Belemnites minimus* occur in this passage bed, which I believe to form the real base of the overlying Upper Cretaceous series. (But see foot-note on p. 15.)

Description of Sections.

Sand has been dug by the roadside half a mile north of Gunby Hall, but the first open section is a small pit about three furlongs N.N.W. of Candlesby. This shows about 10 feet of coarse brown sand, becoming argillaceous in the top 2 feet which contain calcareo phosphatic nodules; this is overlaid by 2 feet of dark red marl with lumps of harder red rock.

The outcrop of the Carstone is overlapped by Boulder Clay in the valley to the N.W., and it reappears on the other side near Bassingham at a slightly higher level in consequence of a small fault.

Grebby Mill stands on a ridge of this sand, from which the Red rock has been removed by denudation. The sand pit south of the mill showed the following section in 1880 :—

	feet.
3. Yellowish red clay with *Belemnites* - - -	1
2. Greyish-green sandy clay with phosphate nodules; base apparently uneven - - - - -	1½
1. Brown and coarse sand-rock, with coarse arenaceo-phosphate nodules, and hard ferruginous veins striking through the mass at various angles - -	8

Dip apparently about 3° or 4° to the N.

There is a slight appearance of unconformity between Nos. 1 and 2, so that the greenish sandy clay which is often seen elsewhere at the top of the brown sands has probably been formed partially by the detrition of the underlying beds and should be regarded as the basement bed of the Red Chalk. The wells at the mill and cottages near are dug completely through the sands into a bluish clay, the total depth being from 37 to 40 feet; consequently the thickness of the Carstone here is from 30 to 35 feet.

Behind Grebby Hall the sand forms a steep slope facing the west, which is occupied by a long copse or wood.

West of Skendleby its outcrop forms the usual bank below the Chalk, and is traceable as far as the spring W. of Skendleby Lodge; here it seems to be very thin for an artificial water-channel has been cut through shaly sandstone, with bands of dark brown ironstone (see p. 20). This point is at the entrance to a long narrow valley which penetrates into the Chalk hills beyond Dexthorpe, and is cut down through the Carstone into the clays below. Strong springs are thrown from numerous points on either side of this valley, especially near its head where it bifurcates into two smaller hollows, and it is doubtless to the action of these that this narrow glen owes its origin and extraordinary extension.

This valley is succeeded by an equally curious promontory, round which the outcrop of the brown sand may be followed, forming a prominent bank near Skendleby Thorpe. About two furlongs N.W. of the farm so named this bank is cut through by the cart-road, and the following beds are exposed :—

	feet.
Red Limestone, with partings of red clay, and containing *Terebratula biplicata* and *Belemnites minimus* - -	3
Sandy and loamy clay, mottled red and yellow, with some arenaceo-phosphatic nodules - - - -	2
Loose yellow sand - - - - - -	2

Thickness of sand in well at the farm about 30 feet.

From here the outcrop curves round with that of the Red Rock into a narrow glen, parallel and similar to that just described, but not nearly so long. Thence the escarpment passes westward through Dalby Park; 15 to 20 feet of the coarse brown sand is exposed in a pit at the back of the hall, and in a road-cutting made in 1881 above this the Red Chalk was seen, resting on a stiff greenish sand full of phosphate nodules, and passing down into yellowish brown sand of which about 15 feet was seen at the western end. About a foot below the green sand is a line of calcareous concretions; yellowish-brown sand caps the ridge of ironstone over which the road passes to the S.W. of Dalby, and can be seen in the bank by the side of the main road.

Between Dalby and Langton there are several diminutive combes round which outcrops of the Red Rock, and Brown Sand may be traced, both giving out numerous springs of clear sparkling water, and the growth of flowers and vividly green herbage which surrounds the springs makes these little hollows exceedingly picturesque. Near Langton the slopes are continuously wooded, but a good section of these beds is to be found by the roadside north of Langton Hall.

A large excavation has here been made for obtaining sand, exposing more than 20 feet of the Carstone; the beds appear to dip northward at about 15°, but this stratification may not be true bedding. The lower part is a soft ironshot rock or brown sandstone with black ferruginous veins; this passes up into coarser sands, yellow and brown, containing large quartz grains and small pebbles; towards the top these become yellowish-white, and contain calcareo-phosphatic concretions; the next division is about 3 feet of tough sandy clays, mottled green, red, and brown, probably from the infiltration of iron; these pass into a red and laminated sandy clay, which forms the base of the Red Limestone; there is about a foot of this between the mottled clays and the first layer of hard red rock, and in this sandy clay I found *Belemnites minimus* and *Terebratula biplicata*, as well as phosphatic nodules. Mr. Strahan, who also visited this locality, took the following measured section :—

		ft.	in.
Red Chalk.	Red nodular chalk, with deep red clay partings and with black grains scattered throughout. *Terebratula biplicata, Belemnites minimus,* and fragments of *Inoceramus* abundant (top not seen) - - - -	2	6
	Red clay, with yellow streaks, about 6 inches thick, with *Belemnites* and *Inoceramus*, passing down into unfossiliferous yellowish and red, very gritty clay with cylindrical concretions, altogether - - -	1	6
Carstone.	Loose sand with a few small pebbles - - -	1	10
	Line of large whitish phosphatic and ferruginous concretions, averaging 6 × 4 × 4 inches - - -	0	6
	Pebbly band, with small quartz pebbles and rolled phosphatic nodules - - - - -	4	0
	Sand, with rolled phosphatic nodules scattered throughout - - - - - - -	4	0
	Sand, with irregular veins of black iron oxide - -	18	0+
		32	4

Although when examined thus closely there seems to be a complete passage from one formation into the other, it will be noticed, if viewed from a little distance, that the base line of the Red Rock is slightly undulating, and that the mottled clay seems to follow it as if it had resulted from the working up of the beds below. In the pit there is a well which is said to have been dug through 15 feet of grey and white sand, and that water was found in white sand which rested on a kind of "soapy fuller's earth." The thickness of the Carstone here is therefore about 40 feet.

The brown sand, overlaid by greenish clayey sand and red marl with Belemnites, is seen again in the combe midway between Langton and

Sutterby, and thence it is traceable as a strip of brown sandy soil round the head of the deep and picturesque combe east of Sutterby.

By the road side N. of Sutterby Church there is a small sand pit showing 5 or 6 feet of coarse brown sand, mottled with red stains from the infiltration of iron from the Red Rock above; the relation of the Chalk to these sands is discussed on page 47. The outcrop of the latter is very narrow, and their thickness here cannot be more than 25 or 30 feet.

Yellow and brown sands are visible in the road-cutting on Harrington Hill, and in tracing their outcrop eastward by the cottage below the wood I found some greenish-grey clay, apparently just beneath the Red Rock.

At the cottage near the chalk pit, south of Brinkhill, the beds below the chalk met with in sinking the well are said to have been 4 feet of greyish-white soapy clay, with 30 feet brown and reddish sand underneath. (See Appendix B., p. 151.) They did not find water, and the springs on the western slope are apparently thrown out by this clay seam at the base of the Chalk.

The main outcrop of the Carstone is cut off by the Driby and Ormsby fault, and its feature is not seen again till we reach the combe south of Dog Hill, near Worlaby. Thence it is traceable round Holster Dale and along the escarpment north of Tetford, but no good exposures were seen either by myself or Mr. Strahan except at Tithe Farm, near Belchford, of which my colleague, Mr. Strahan, gives the following account:—

		feet.
"White nodular chalk with so-called *Spongia paradoxica* - - - - - -		3
Red Chalk	Red nodular chalk with fragments of *Inoceramus* and *Spongia paradoxica* -	10
	Passing down into red marl with *Belemnites minimus* abundant, and containing veins of greenish-yellow marl below - - - -	2
Carstone	Yellowish-green gritty clay with quartz grains passing down into yellow and brown sandstone (Carstone), with flakes of iron oxide and grains of quartz (base not clearly seen) -	35 (about)

"The same junction is exposed at the north end of Gaumer Hill, but there the white and red chalk are much displaced by slipping. About two feet below the red marl, described above as occurring at the base of the Red Chalk, there are two bands of concretions, consisting principally of the usual constituents of the Carstone fixed in a ferruginous and slightly phosphatic cement. The concretions take the form of hollow cylinders or very irregular spheres. They may be traced at almost exactly the same distance below the base of the Red Chalk for many miles along the escarpment."

Outliers.

The hill south of Dalby is a promontory of the "roach," capped by an outlier of the Carstone, which is seen in the road-cutting. The ridges west of Brinkhill, called Warden Hill and Cloven Hill, consist of two elongate outliers of this sand resting on a platform of ironstone rock and capped by several still smaller outliers of red and white chalk. They admirably illustrate the manner in which such isolated patches of sand and chalk are wasted by the action of rain, frost, and springs; there can be no doubt that at one time these ridges were connected with the larger outlier near South Ormsby, and were capped with a continuous sheet of chalk. The two gaps by which this mass is now separated into three portions are due to the recession of spring-heads in the first place, assisted and completed by the action of rain. Every shower which falls on these ridges washes some of the sand down the slopes, so that an observer who

happens to be caught in a shower on Warden or Cloven Hill can watch the actual process which has in the course of centuries reduced these hills to their present narrow proportions.

In connexion with this subject it is also interesting to compare the two promontories which project from the escarpment to the north-west of Tetford, viz., that on which Tetford Parsonage stands, and that called Gaumer Hill, a mile and a half north of Belchford, with the complete outlier near Belchford Wood; the Parsonage Hill is an outlier of chalk only, the underlying sand being still continuous with the main outcrop; at Gaumer Hill the isolation is carried a step further, the sands being severed and the promontory only connected with the escarpment by a neck of the roach or ironstone bed; finally, in the hill north of Belchford we have a complete outlier of the ironstone bed, but still surmounted by successive cappings of the Carstone, Red Chalk, and Grey Chalk.

Inliers.

The most southerly inliers are those in the valley, which runs from Claxby to Ulceby; the Carstone is exposed here in several places, and a description of the locality will be found in Chapter V., p. 49. It is worthy of remark that at Skendleby Salter the width of the bank between the outcrop of the Red Chalk and the ironstone in the pond below is very small, and would not represent a thickness of more than 12 or 15 feet for the Carstone (compare Skendleby, p. 24).

Round the great Oxcombe and Farforth inlier yellow and brown sands everywhere underlie the Red Chalk, but no open sections were visible at the time it was surveyed, except a small pit about 6 furlongs W.S.W. of Ruckland, which exposed a few feet of coarse brown sand overlaid by rubble of Red Chalk. The same sand was seen in the road below the outcrop of the red rock north of Worlaby, and yellow sands are thrown out of rabbit holes in the deep combe to the south-west of Worlaby.

The only other inlier is a very small one, south-west of Withcall; a sand pit in this on the north side of the valley shows 2 feet of Red Chalk rubble resting on 6 feet of coarse yellowish-brown sand with a line of calcareous concretions. This small patch seems to be brought up between two faults nearly at right angles to each other, for at the farm close by there is more than 20 feet of white chalk in the well.

CHAPTER IV.

THE CHALK (UPPER CRETACEOUS).

General Description.

In the south of England the Chalk maintains the same general appearance and exhibits a similar succession of beds over a wide extent of ground, and this typical facies of the Chalk is known to extend as far north as the neighbourhood of Cambridge and Newmarket.

In Lincolnshire the Chalk puts on a different facies and presents many points of contrast: its basement bed is a zone of hard brick-red rock (like that seen at Hunstanton); it contains no zone of soft marl comparable to the Chalk Marl of southern England, but beds of pink marl occur high up in the Lower Chalk; the change from chalk without flints to chalk with flints is sudden and complete, instead of being very gradual as it is in Cambridgeshire and elsewhere. The mass of the Lincolnshire Chalk, and especially that with flints, is much harder than the corresponding portion in southern districts.

The Chalk of Lincolnshire falls naturally into two great divisions, which appear to correspond roughly with the Lower and Middle Chalk respectively, but the zonal subdivisions are not so marked or so well developed as they are in Cambridgeshire.* Moreover, as the zones of the latter county have not yet been traced northward into Norfolk, where the Chalk begins to put on what may be termed the northern or Lincolnshire facies, the data requisite for the proper correlation of the two areas are therefore incomplete.

The Red Chalk has always been regarded as the base of the Upper Cretaceous series in Yorkshire and Lincolnshire, but whether it corresponds to any one particular stage of the series found in the southern counties or whether it is a condensed equivalent of all the beds which there intervene between the Lower Greensand and the Chalk Marl is a disputed question, the discussion of which would be beyond the scope of the present memoir. It may be useful, however, to draw attention to certain facts and points of comparison between the Red Chalk of Lincolnshire and that of Hunstanton; (1) the Red Chalk of the Lincolnshire Wolds is an amplified counterpart of that seen at Hunstanton, being nearly three times as thick, but having

* See Geology of the Neighbourhood of Cambridge, Mem. Geol. Survey, by W. H. Penning and A. J. Jukes-Browne, p. 21.

similar characters and exhibiting similar gradations of colour; (2) the bed or beds, answering to that called the "Sponge Bed" at Hunstanton, are in Lincolnshire of a yellowish pink colour; (3) in the lower half of the rock *Belemnites minimus* and *Terebratula biplicata* are abundant, in the upper half the *Belemnite* is absent or rare, and *Avicula gryphæoides* is common; (4) no Cephalopods have yet been obtained from the Lincolnshire beds, though certain species occur at Hunstanton.

The bed of hard grey gritty rock (*Inoceramus Bed*) which lies above the Red Chalk at Hunstanton is also present everywhere in Lincolnshire; it recalls the aspect of the Totternhoe Stone, and may perhaps be regarded as its attenuated representative.*

The overlying beds appear to belong to the zone of *Holaster subglobosus*, that fossil and others characteristic of the zone being prevalent throughout. The bands of pink chalk so well exposed in the quarries near Louth occur in the upper part of this zone, but they are not continuous throughout Lincolnshire.

Above this division there is a bed of shaly marl, generally buff or grey, often coloured and variegated with red and dull purple, and containing at its base rolled pebbles of hard chalk. This is one of the most constant horizons in Lincolnshire, and I am inclined to correlate it with the marl beds containing *Belemnitella plena* in the midland and southern counties, although the characteristic Belemnite has not yet been found in Lincolnshire.

Between this band and the chalk with flints there are beds of yellowish-white chalk from 12 to 14 feet thick, which are not unlike those of the Melbourn Rock in Cambridgeshire. Moreover, they contain an abundance of *Inoceramus mytiloides* (= *labiatus*), with *Rhynchonella Cuvieri*, and I am inclined to regard them as representing not only the Melbourn Rock, but the whole of the zone of *Rhynchonella Cuvieri*†.

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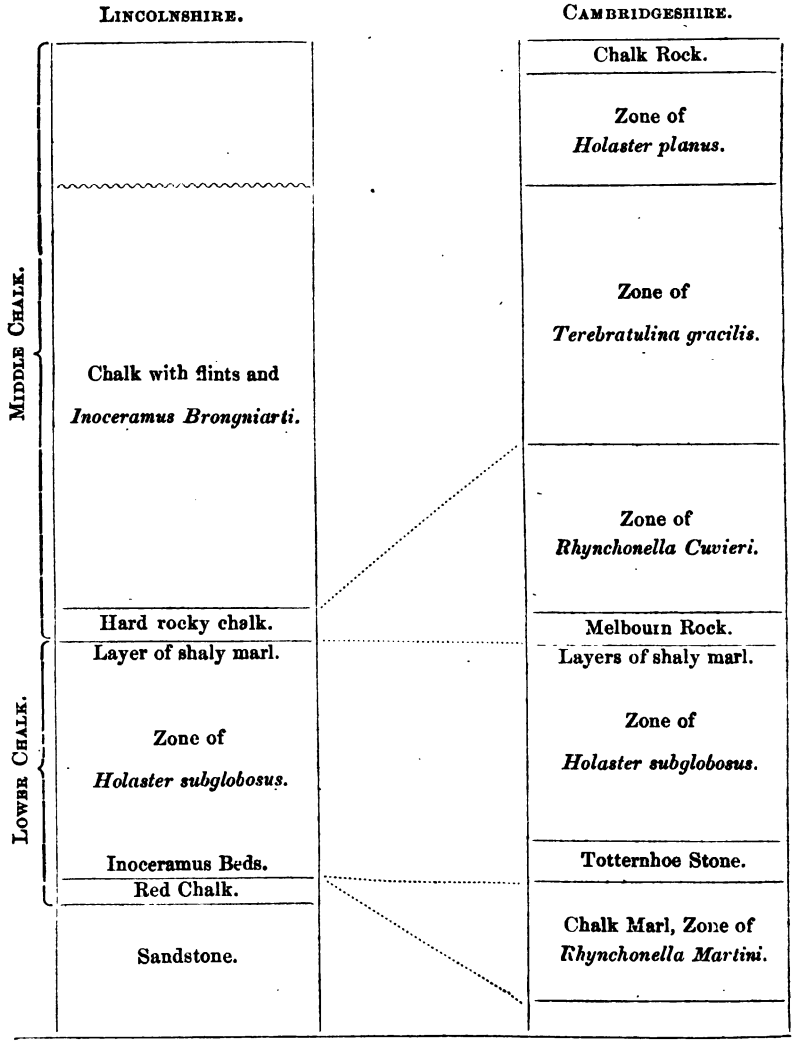
* Since the above was written the Lower Chalk of Norfolk has been examined by Mr. W. Hill, and the author; the Chalk Marl was found to pass laterally into the lower part of the hard Norfolk Chalk; the Totternhoe Stone is represented by a band of grey gritty chalk, which seems to lose some of its distinctive characters as it is followed northward, but can still be distinguished at Hunstanton about 12 feet above the Inoceramus Bed. The Upper part of the Lower Chalk in Norfolk is very thin, thinner even than in Lincolnshire, and is not so clearly marked off from the Melbourn Rock as elsewhere, the intervening marls having thinned out.

† Dr. Barrois gives the name of *Inoceramus labiatus* to this zone.

TABULAR VIEW OF CHALK ZONES.

Scale 80 feet to an inch.



This table was drawn up before the examination of the Norfolk Chalk, referred to on p. 29, was made. Our discoveries in that county make it clear that the representative of the Totternhoe Stone should be sought for in Lincolnshire at a height of 10 or 12 feet above the Inoceramus Beds. These beds themselves, together with a portion of the Grey Chalk above and of the Red Chalk below, appear to be the equivalents of the Chalk Marl of Cambridgeshire.

The chalk with flints is exceedingly uniform in character and particularly poor in fossils, except *Inocerami*, which are tolerably abundant; these *Inocerami* belong principally to the species *Brongniarti*, Sow, *involutus*, Mant., and ? *cuneiformis*, D'Orb.; the two former characterise the zones of *Terebratulina gracilis* and *Holaster planus* in the south of England, and I think, therefore, that the Lincolnshire chalk with flints may be considered to contain the representatives of these two zones. The two Echinoderms found by Mr. Rhodes near Louth, *Echinoconus globulus* and *Infulaster excentricus*, are both Middle Chalk forms.

The upper limit of the Middle Chalk, or Turonien, is not seen anywhere in Lincolnshire, and must be sought for on the north side of the Humber.

The correlation above indicated is displayed in a tabular view on p. 30. As yet, however, we know nothing of the changes which the Chalk zones undergo in their passage from Cambridge into Norfolk; and in the absence of this connecting stratigraphical evidence the correlations now suggested are not to be received as a decided expression of opinion, but must await confirmation or refutation by the light of further researches in Norfolk.* It would appear also that the zonal distribution of species which holds good over the greater part of England is subject to remarkable exceptions in Lincolnshire (see Appendix A., p. 146).

It only remains for me to point out how far these divisions agree with those suggested by Dr. Barrois for the Louth Chalk,† and by Dr. Barrois‡ and Prof. J. F. Blake§ for the Chalk of Yorkshire. As regards Lincolnshire, Dr. Barrois says that he did not visit that county, and that his comparisons have not, therefore, the same value as in the case of sections which he had personally inspected. He briefly compares the Louth Chalk with pink bands with the zone of *Inoceramus labiatus* in Norfolk, while I prefer to consider it as a portion of the *Holaster subglobosus* zone, and limit the former zone to the very uppermost part of the chalk without flints. In the same way it seems to me that at Speeton he has included too little in the lower zone and too much in the higher zone, but I cannot speak from personal knowledge of that section.

On the other hand, Prof. Blake seems to err in grouping all the grey beds below the chalk with flints together in the zone of *H. subglobosus*, and in referring the overlying chalk with flints to the zone of *Inoc. mytiloides* (*labiatus*). Dr. Barrois' criticisms on Prof. Blake's paper‖ are quite in accordance with

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* Recent researches have I think confirmed it (see ante p. 30, note).
† Recherches sur le Terrain Crétacé supérieur, p. 189.
‡ Op. cit., p. 191.
§ Proc. Geol. Assoc., vol. v., p. 232.
‖ Proc. Geol. Assoc., vol. vi., p. 165.

my experience in Lincolnshire; the horizon where *Inoceramus mytiloides* abounds is below the chalk with flints, and it occurs but rarely in the latter, where *Inoc. Brongniarti* and *Inoc. undulatus* are certainly the prevalent forms. The line of division between these two zones is the horizon on which the flints first present themselves, accompanied by a marked difference in the colour and lithological character of the chalk. Stratigraphically, however, this line is not so marked and important as that which I have taken to divide the Lower and Middle Chalk.

To sum up, there would appear to be a decided thinning out of the zones in the lower part of the Chalk. The Chalk Marl has almost disappeared; the Totternhoe Stone is only found, if at all, in an attenuated form; the Melbourn Rock and zone of *Rhynchonella Cuvieri* are inseparable from one another, and are not more than 15 feet in thickness; so that a portion of the Chalk which in Cambridge is 220 feet thick has dwindled down to a thickness of about 100 feet in Lincolnshire.

Before entering upon the detailed description of the actual sections seen in Sheet 84, it will be well to give a general account of the beds which compose the Lower and Middle Chalk of Lincolnshire.

The Lower Chalk.

This division includes two zones, the Red Chalk or zone of *Belemnites minimus*, and the Grey Chalk or zone of *Holaster subglobosus*.

1. The Red Chalk varies little in thickness throughout this part of Lincolnshire, being everywhere about 11 or 12 feet thick. Its relation to the underlying sandstone has already been described; its lowermost bed is a deep red marl full of *Belemnites minimus;* this is succeeded by layers of hard brick-red rock, rough and nodular in appearance, containing many *Terebratulæ, Belemnites,* and small shining fragments of quartz and lydian stone derived from the underlying sands; the layers are separated by seams of soft red marl, and the upper beds are much lighter in colour, being rather pink than red, and there is usually a bed of yellowish-pink chalk at the top. This is overlaid by a band of hard nodular yellowish-grey chalk, weathering into rough lumps; both this and the pink beds below frequently contain the structures known as *Spongia paradoxica.* Sometimes the red, pink and yellow portions are separated by well marked lines of division, but in other localities they seem to pass into one another.

The following is an analysis of a sample of red chalk taken about seven feet above the basement red marl from a pit on Nob Hill near Donnington in Sheet 83. The analysis was

kindly made for me by Mr. Meaburn Staniland, junr., in the laboratory of the Science Schools at South Kensington.

Insoluble in Hydrochloric acid:—		
Silica	4·49	
Peroxide of iron	1·56	— 6·05
Soluble portion:—		
Lime	49·36	
Peroxide of iron	1·96	
Magnesia	1·10	
Carbonic acid	41·20	
Phosphoric acid	Trace.	
Moisture	1·08	— 94·70
		100·75

A microscopical examination of the rock showed that numerous Foraminifera and many small grains of Quartz were scattered through the mass.

The Grey Chalk has a thickness of between 70 and 80 feet. At its base occur two or three courses of hard grey gritty stone about 5 feet thick, and crowded with broken fragments of *Inoceramus*. The lower layer is generally nodular, but the upper course is massive and evenly bedded. These layers are identical with the so-called *Inoceramus* bed of Hunstanton, and appear to represent a part of the Chalk Marl. An analysis of a specimen of this stone from the lime kilns north of Gaumer Hill by Mr. M. Staniland, junr., is given below.

Insoluble portion:—		
Silica and Alumina		3·01
Soluble portion:—		
Lime	52·44	
Peroxide of iron	1·50	
Magnesia	0·70	
Carbonic acid	41·71	
Moisture	0·56	— 96·91
		99·92

It is evident from this analysis that the grittiness of the rock is due to the comminuted fragments of Inoceramus shell which consists of Arragonite, the hardest form of carbonate of lime; it has often been described as a sandy stone, but there appears to be no real sand in it at all.

Above the Inoceramus beds there is some thickness of hard grey chalk, for the most part rough and nodular, with partings of gritty shale, but containing some courses of more compact greyish-white chalk, which ring under the hammer. These beds must be between 30 and 40 feet thick. They are succeeded by a series of greyish-white beds, less nodular and more evenly bedded, in which two bands of pink marly chalk are locally developed, each about 7 feet thick near Louth. No trace of these pink bands was found at the southern end of the Wolds along the tract between Candlesby and Driby High Barn, and they were first observed in a pit beyond the latter place

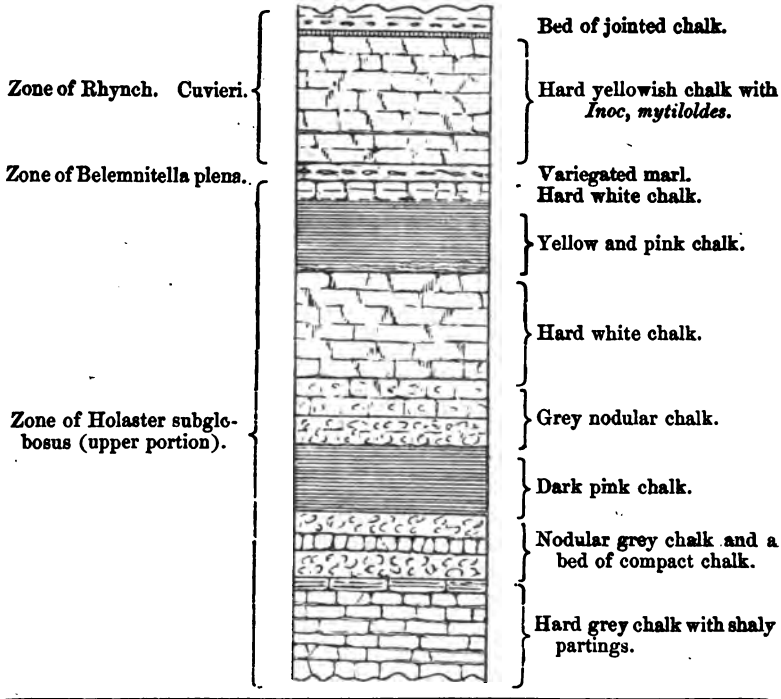
about half a mile S.E. of Calceby. Good exposures of them occur at South Thoresby and Swaby, and still better sections are visible in the numerous quarries near Louth. They have also been seen at several localities in Sheet 83, but appear to die out in that sheet, and are not found in the neighbourhood of Caistor. The length of the area over which they extend from S.E. to N.W. seems to be only about 15 to 16 miles, with a breadth near Louth of about 5 miles.

The thickness of these grey and pink beds measured from the base of the nodular grey chalk underlying the lower pink course to the base of the variegated marl band is about 42 feet, and the position of the several courses is shown in the tabular view, Fig. 5, which is drawn to scale from measurements taken in the several quarries near Louth. The thickness of the underlying grey chalk from the horizon above indicated to the top of the red (Hunstanton) rock I should estimate as about 36 feet.* My reasons for showing only two courses of pink chalk, not three, as supposed by Professor Judd, are given on p. 57.

FIG. 5.

Vertical Section of the Upper Part of the Chalk without Flints near Louth.

Scale, 20 feet to 1 inch.



* These thicknesses are calculated from exposures near Louth, the thickness of Lower Chalk toward the south end of the Wolds may be greater, perhaps 90 feet.

The general eastward dip of the Chalk is so slight that although the breadth of ground occupied by the Lower Chalk above the escarpment is not very great, yet it is exposed in nearly all the valleys which intersect the Wolds and underlies the Glacial beds which are banked against the eastern flank of these hills. If, indeed, the Glacial and Post-glacial beds were cleared away from the eastern part of the district the Grey Chalk would be seen as constituting the platform or foundation upon which they rest (see Plate of Sections at the end of the volume).

Chemical composition.—For the following analyses of specimens taken from the two bands of Pink Chalk, I am indebted to Mr. Meaburn Staniland, junr., by whom they were made in the laboratory at South Kensington:—

	Lower Pink Chalk from Hubbards Hill, Louth.	Upper Pink Chalk from Louth.	Yellow Band in Upper Pink Chalk, Louth.
Insoluble portion	*11·90*	2·10	4·96
Silica	10·80	—	—
Peroxide of iron and alumina	1·10	—	—
Soluble portion:—			
Lime	45·91	53·62	51·72
Alumina	1·35	—	trace
Peroxide of iron	1·03	0·35	1·05
Magnesia	0·71	0·36	0·92
Carbonic acid	36·51	42·86	40·91
Phosphoric acid	trace	trace	—
Moisture	1·92	0·75	1·20
	99·33	100·04	100·76

Mr. Staniland has favoured me with the following observations on these analyses, and on that of the basement red rock given on p. 33.

"The first point which appears deserving of notice is the amount of iron they contain as compared with the degree of colour in the rock, and I think from the results obtained it is clear that the iron is present in two distinct forms; one in which it colours the rock more or less red, and which may, therefore, be called the 'tinctorial' form, and the other in which it does not affect the colour of the rock at all."

"Taking these chalks which are distinctly coloured, viz., the Red Chalk, Upper Pink Band (Pink part), Lower Pink Band, Upper Pink Band (Yellow), we have in the Upper Pink Chalk,

iron amounting to ·35 per cent., and an Insoluble Residue about 2·10 per cent. The rock is distinctly coloured, showing that ·35 per cent. of $Fe_2 O_3$ is quite sufficient for that purpose. Now if we take the Lower Pink Chalk we find a great increase in the iron, viz., 2·13 per cent. as compared to the ·35 per cent. of the Upper Pink. The Insoluble Residue is likewise very much larger, being 11·9 per cent. as compared to 2·1 per cent. in the former; still the colour of the rock is no deeper, and the reason, I think, must be that the greater part of this iron is in a form which is not tinctorial. The same may be said of the Upper Pink (Yellow), which contains an amount of iron and Insoluble Residue intermediate between the two former chalks, it is nevertheless no more highly coloured than the Upper Pink. The Red Chalk which is the most highly coloured of any, yields an Insoluble Residue containing more than one fifth of its weight of $Fe_2 O_3$, added to which a somewhat larger amount is contained in the soluble portion.

"Now as the Insoluble Residues of these chalks is either colourless or but slightly grey, it is clear that the iron contained in them cannot be in the same state as that which colours the rock. I therefore infer that in all these coloured chalks the iron must be in two distinct states; one in which it is soluble and tinctorial, the other in which it is in some combination attackable with difficulty by strong Hydrochloric Acid, and not as Red Oxide. In each case also the amount of iron varies according to the amount of the insoluble residue, showing that the greater part of the iron is in the combination referred to above."

Mr. Staniland also tells me he thinks there can be little doubt that the whole of this non-tinctorial iron is really in the form of a silicate, though it is impossible to prove this by chemical analysis, because the acid does not stop its action when it has dissolved the peroxide, but proceeds to dissolve some of the less soluble compound as well.

Origin of the Colouring Matter.—It is a point of great importance to ascertain, if possible, whether the pink and yellow colour was imparted to these bands at the time of their deposition or whether the colouring matter has been subsequently introduced.

Hitherto, I believe the former view was generally accepted without inquiry, but Dr. W. Johnstone, has suggested to me that the peroxide of iron originally existed in some thin seam or line of nodules, and that this, carried by currents of water, has stained the chalk through which it passed; this view being suggested by an examination of the Red Chalk of Hunstanton, which he believes to have been coloured in this manner. He would, therefore, regard all such bands of red and pink chalk as having originally been grey or white and subsequently coloured by the introduction of the peroxide of iron.

There are several facts which tell in favour of this theory:—

1. Most red rocks are deficient in organic remains, but these beds of pink chalk, especially the lower band, contain many fossils, and these are, moreover, *of the same species* as characterise the chalk above and below, differing neither in size nor form from the usual individuals of their species.
2. The red colour is darkest in the softer chalk which fills the interstices between the harder lumps and blocks, and when these latter are broken, their interior is found to be of a very pale pink and is sometimes nearly white; this fact is strongly suggestive of staining by percolating water.
3. There is a band of dark red marl in the middle of the lower pink band, and it is possible that the iron-oxide was originally confined to this and has been spread upwards and downwards by the passage of water; upwards by capillary action and downwards by infiltration.
4. In the case of the upper band it is remarkable that it is generally covered by a thin seam or parting of dark red clay or marl, whence the colouring matter may have been derived; also that the colour is darkest at the base of the band, which is soft, marly and shaly.
5. Both bands are marly and shaly at the base, and both sometimes rest upon a thin seam of grey shale, which might be sufficient to prevent the colouring matter being carried lower down.

The limited area over which both the coloured bands extends cannot be used as an argument in favour of either view, for the deposit of iron was likely to be of limited extent, whether it was confined to a thin seam or disseminated (as now) through several feet of chalk. After a careful consideration of the evidence, I am inclined to think that Mr. Johnstone's explanation is very probably correct, and trust that the investigation which he is now prosecuting may enable him to establish it.

The Middle Chalk

That part of this division which comes within our area also includes two zones; the lower being that of *Inoceramus mytiloides* and consisting of yellowish white chalk without flints; the upper may be called the zone of *Inoceramus Brongniarti*, and consists of compact white chalk with layers of flint nodules. The combined thickness of these zones to the north of Louth cannot be far short of 200 feet.

1. *Zone of Inoceramus mytiloides.*

The band of variegated marl or fuller's earth which lies at the base of this Zone extends, I believe, throughout Lincolnshire, though it is not always coloured with the red and purple tints

which characterise it near Louth and South Thoresby. Its thickness is about 2 feet, and its colour is buff and slate-grey, with occasional layers of dull red or purplish marl, and consequently it forms a very conspicuous feature in the pits where it is exposed. Its basement layer is always full of small lumps or nodules of hard chalk, with a yellowish exterior, as if derived from the breaking up of some older beds. I have also noticed in several places, where the chalk was otherwise undisturbed, that the base line of the shaly marl is slightly undulating, as if it rested on a surface of erosion. The very existence of this mud-band indicates a change in the surrounding physical conditions and the irruption of a mud-bearing current. Moreover, there are indications of a break at what seems to be the same horizon in other parts of England, and nearly all the fossils which are found in the zone below are absent from the chalk above.

Fossils are scarce in this marl, but it is noticeable that the teeth and bones of fish are the most frequent. (See list in Appendix A., p. 146.)

A workman in one of the quarries at Louth gave me a small round flint nodule which he said he had taken out of this band, remarking that he had never found one in it before.

Three analyses of portions of this marl band are subjoined:—

A is a purple marl taken from a pit S.E. of Gayton le Wold in sheet 83, and was analysed by Mr. M. Staniland;

B is from the same locality, a grey marl overlying the purple band, and analysed by Mr. M. Staniland;

C is a purple marl from the quarry near Louth Cemetery, analysed by Mr. Grant-Wilson of the Geological Survey.

	A.	B.	C.
Insoluble in HCl.:—			
Silica	6·62	22·50	14·46
Alumina	2·18*	5·54*	4·61
Peroxide of iron			·83
Lime	·52	—	·31
Magnesia	—	—	·73
Loss on ignition	—	—	1·17
Soluble portion:—			
Lime	48·16	34·98	34·51
Alumina	—	2·40	·65
Peroxide of iron	1·35	1·57	1·59
Protoxide of iron	—	—	·64
Protoxide of Manganese	—	—	3·20
Magnesia	0·45	1·94	2·61
Carbonic acid	38·44	27–00	30·14
Phosphoric acid	—	trace	·68
Water	1·62	2·40	5·10
	99·24	98·33	101·23

* The Iron was not separated from the Alumina in these samples, but the greater portion is doubtless Alumina.

The observations made by Mr. Staniland with regard to the red-coloured chalks are applicable also to these marls, if indeed the iron is the colouring matter in this case; the amount of soluble iron is as great in the case of the grey marl (B) as in the purple marl (C), while the amount of manganese in the latter seems to indicate that mineral as the colouring agent, and its existence in the sample A may have been overlooked.

Overlying the marl band there are generally two or three feet of greyish-white chalk, with shaly partings, surmounted by a layer of buff or grey shale containing fragments of *Inoceramus mytiloides* and small lumps or nodules of hard chalk; above this the chalk is yellowish or greyish, in thicker beds, and full of fragments of Inoceramus shell, which cause it to feel very gritty to the hand. A sample of this was sent to Mr. Grant-Wilson for analysis, who finds its composition to be as follows; the amount of Magnesia is unusually large, and he suggests that part of it is in combination with the Silica.

Insoluble in HCl. (chiefly Silica)	3·62
Soluble portion:—	
Lime	49·79
Magnesia	5·33
Alumina	·34
Protoxide of Iron	·55
Protoxide of Manganese	trace
Carbonic Acid	40·12
Sulphuric Acid	·55
	100·30

This portion is 9 or 10 feet thick, and becomes very shaly at the top; the upper 6 or 9 inches frequently being a grey shale enclosing thin layers of harder chalk. The fossils found in this chalk are given in the Appendix A., p. 146. A peculiar variety of *Ostrea vesicularis* is not uncommon in the shaly beds, and is identical with the form so common in the marls of the *Bel. plena* zone of Cambridgeshire.

2. *Zone of Inoceramus Brongniartii.*

Resting on the grey shaly chalk of the underlying zone there is generally a thin layer of white compact chalk, which I have been accustomed to speak of as "the columnar bed;" this layer is never more than 6 inches thick, and is traversed by numerous close-set vertical joints, so that when exposed to the action of frost and weather it breaks up into small and narrow rectangular blocks, which, when viewed from the front, look like a number of small columns. The whiteness and vertical jointing of this bed form a marked contrast to the greyness and horizontal lamination of the underlying chalk.

Its chemical composition is also very different as will be seen from the following analysis made by my colleague, Mr. Grant-Wilson:—

Insoluble in HCl. (chiefly Alumina) - - -	1·06
Soluble portion:—	
Lime - - - - - -	54·63
Magnesia - - - - -	·39
Alumina - - - - -	·24
Protoxide of Iron - - - -	·35
Protoxide of Manganese - - - -	trace
Carbonic Acid - - - - -	43·05
Sulphuric Acid - - - - -	·45
	101·17

The overlying chalk is of a pure creamy white, compact, evenly-bedded, and containing numerous nodules of grey flint in regular lines, one line of nodules being generally near the base. No one examining a quarry in this part of the chalk can fail to be struck by the fact that the flints are traversed by the same joint planes as the chalk in which they are embedded. Moreover, the flints adhere closely to the surrounding chalk, so that when the blocks are quarried out, the line of fracture passes evenly and smoothly through chalk and flint alike, each portion of the flint-nodule remaining in the block to which it belongs. Even when these blocks are broken up and the flints detached, it frequently happens that portions of the chalk still adhere to their outer surface. Thin seams of dark grey marl or pipe-clay are not uncommon in this chalk, and occasionally there is a continuous layer of darker flint, but this is exceptional.

In some cases the flint nodules are surrounded by an outer rind or layer of chalky matter, which adheres to the nodule, but can easily be separated from it; this material has a gritty feel, and the layer varies from a quarter to half an inch in thickness. In order to ascertain how far this differed from ordinary chalk, a specimen was sent to Mr. Staniland who has furnished me with the following analysis. The sample was taken from a pit near Cadeby House in the S.E. corner of Sheet 83.

Insoluble in HCl.:—		
Silica - - - -	45·12	
Peroxide of iron - - -	1·43	— 46·55
Soluble portion:—		
Lime - - - - -	27·88	
Peroxide of iron - - -	1·73	
Alumina - - - -	trace	
Magnesia - - - -	trace	
Carbonic acid - - -	22·65	
Phosphoric acid - - -	trace	
Moisture - - - -	1·06	— 53·32
		99·87

Mr. Staniland reports that "an examination of the specimen disclosed the fact that visible pieces of Chalcedony are scattered through it; these were sifted out after gently crushing the material, and were separated from the portion analysed, notwithstanding which there still remained the large amount of silica in the insoluble residue (45 per cent.). This was examined microscopically and found to contain numerous *Coccoliths* and some silicified *Globigerina*." These results are very interesting and suggest the supposition that this coating layer contains the surplus silica which was not required for the formation of the flint nodule.

The chalk with nodular flints passes up into chalk with layers of flint, which are more or less continuous and are very peculiar in their structure. Some of them are quite continuous, thickening and thinning lenticularly and splitting into shaly fragments parallel to the general plane of stratification; these layers also frequently include thin seams of chalk, which are evidently interstratified with the flint. Other layers contain quite as much chalk as flint, the two ingredients being so intricately arranged and intermingled that the layer looks like a breccia of small flint fragments embedded in a matrix of hard chalk; and what is still more curious the whole behaves as if it were a homogeneous bed, its upper and lower surfaces being sharply defined and more or less mammillated. These layers are usually about 4 or 5 inches thick, and the flint is always either of light grey or light brown tint.

I was so struck with the peculiarity of these layers that I wondered whether the associated chalky matter contained a larger proportion of silica than usual, like the coating of the flints above described. A sample was therefore submitted to Mr. Grant-Wilson for analysis, but it proves to be a pure chalk with only a very small amount of silica. The analysis is subjoined:—

Insoluble in HCl. (chiefly Silica)	1·37
Soluble portion:	
Lime	53·91
Magnesia	·18
Alumina	·16
Protoxide of Iron	·27
Protoxide of Manganese	trace
Carbonic Acid	42·35
Sulphuric Acid	·05
Water	·75
	99·14

To illustrate the similarity which exists between the beds above the band of variegated marl in Lincolnshire and the beds at the base of the Middle Chalk in the counties of Cambridge and Hertford, I append a section of these beds at Ashwell, which I saw in 1880, after having made

some acquaintance with the Lincolnshire Chalk. It occurs in a large quarry a quarter of a mile S.E. of Ashwell Church, and is as follows:—

		feet.
4.	White chalk in thin beds	12
	Thin layer of white chalk broken into small pieces by frequent vertical joints	0½
	Rather soft white chalk in thin beds	2
3.	Hard yellowish rocky chalk in three courses	3½
	Softer yellowish shaly chalk, with green streaks	2
	Hard creamy white nodular chalk	3½
2.	Greyish chalk passing up into shale	2
	Hard white chalk	1
	Greenish grey chalk, brittle and shaly	1
1.	Whitish chalk irregularly bedded, belonging to the zone of *Holaster subglobosus*	30

The beds grouped as 2 in the above section form the zone of *Belemnitella plena;* those grouped as 3 form the Melbourn Rock; those numbered 4 are part of the zone of *Rhynchonella Cuvieri*. Now the most curious coincidence is the occurrence of the thin vertically jointed layer in the middle of these upper beds, the aspect of which is exactly the same as that of the layer at the base of the chalk with flints in Lincolnshire. I do not, of course, mean to say that these are identical beds, but it is remarkable that a precisely similar layer should exist in counties so far apart on what I take to be nearly the same horizon.

CHAPTER V.

LOWER CHALK.

Description of Sections.

In describing the sections observed in the various pits and quarries which have been opened in the Lower Chalk, it will be convenient first to take those exposing either the Red Chalk or the basement beds of the Grey Chalk, because there are so many places where both are seen in the same quarry; afterwards, those pits and cuttings which expose the upper beds will be indicated. The sections will be taken as nearly as possible in order proceeding from south-east to north-west.

§ 1. Basement Beds.

Main Outcrop.

The first and most easterly exposure of the Red Rock is about half way between the villages of Welton and Gunby, in a field on the east side of the road, where a small pit was freshly open in 1879, and the following beds were visible :—

	ft.	in.
Rubble formed of the Inoceramus beds	2	0
Layer of greyish laminated marl	0	2
Hard nodular grey chalk	1	0
Hard pink nodular rock, termed "*clunch*"	0	9
Course of hard nodular yellowish rock, often called by the workmen "bastard red"	2	0
Red rock with layers of red marl: this is the "red kalk" of the workmen	4	6
Soft brick-red marl, called the "putty course," and forming the floor of the pit	0	4
About	10	0

A layer of dark red marl forms a clear separation between the "red kalk" and the yellow course or "bastard red." The dip is northerly at 3 or 4 degrees, and consequently the strike here is nearly east and west.

In the quarry 2½ furlongs S.E. of Welton Mill, north of Candlesby, the floor of the pit consists of the topmost bed of the Red Rock. The northern face shows the following section :—

	feet.
Thin bedded chalk, not so hard as that below, with occasional layers of yellowish marl	12
Layer of grey marl, persistent	0⅛
Hard greyish chalk	7
Hard grey rocky chalk	1½
Grey chalk with black stains on joint faces; bluish when damp, and called the blue-course by the workmen	3
Persistent layer of soft grey marl	0⅛
Hard grey gritty chalk, with fragments of *Inoceramus*	3½
Layer of gritty and shaly marl	
Hard grey gritty rock, with *Inoceramus*, and including two layers of shaly marl	2½
Reddish-yellow nodular chalk (*T. biplicata*)	1
About	30

The beds dip slightly to the north, and there are several small slips with slickenside faces, but none of any considerable throw. The pit is worked by Mr. Wholey, and it is the middle beds that are chiefly burnt for lime.

Near the cross road south of Welton Mill there are four chalk pits, but only two of these are now worked: that on the east side of road to the Mill, and opposite the Cross-Keys Inn, shows 30 feet of the Grey Chalk which overlies the Red Chalk. At the north corner the following succession was measured:—

	feet.
Thin-bedded rubbly chalk, with persistent layers of shaly buff coloured marl containing *Terebratulina gracilis*	10
Very hard nodular grey chalk, irregularly bedded (*Rhynchonella mantelliana* and *Ostrea vesicularis*)	3
Hard grey chalk in thin beds with partings of laminated marl	6
Hard grey chalk in beds about a foot thick	5
	24

Several small faults with downthrow to the S. strike across the pit from east to west, and one of them has a throw of about 4 feet; these impart a northerly dip to the beds, but its amount varies.

The lowermost beds in the S.W. corner are bluish-grey, with black stains on the joint faces; this resembles the blue course seen in the pits below, about 6 feet above the Red Rock. The uppermost 10 or 12 feet form a distinct band, are less hard and more fossiliferous, containing *Holaster subglobosus*, *Pecten orbicularis*, *Terebratula semiglobosa*, *Rhynchonella Cuvieri*, and *Vermicularia*, sp.

The other quarry (worked for lime by Mr. Rutter) is on the west side of the road to Candlesby, and about half a mile north of that village. Here a better section is exposed, and the following are the combined measurements taken in the lower and upper parts of the quarry:—

	feet.
Rubbly soil	1
Platy chalk, with two layers of grey laminated marl	4
Whitish chalk, lumpy and irregularly bedded	14
"Blue course," bluish chalk, drying nearly white, with black-stained joint faces	3
Grey gritty chalk (*Inoceramus*) in two thick courses	4
Irregular layer of shaly marl	–
Hard nodular grey chalk, with *Inoceramus*	1
Irregular layer of shaly marl (*Inoceramus*)	–
Hard nodular pink and yellow rock	2
Layer of red marl, forming line of separation	–
Red rock, the top bed being yellowish and the lower beds dark red; with marly partings	6½
About	35

A "wash" or fault crosses the pit from E. to W., with an upthrow of 2 or 3 feet on the south side; the beds dip northward slightly and unevenly. The blue course is said to make the best lime.

South of this the Red Rock appears to be brought up by a fault striking east and west, and some thickness of it is seen by an old kiln on the west side of the road.

The next section in which the basement beds are seen is in a chalk-pit N.E. of Grebby Hall: here the measurements taken were as follows:—

	ft.	in.
Thin-bedded chalk, weathering into nodular lumps, with marly bands	5	0
Band of hard white chalk	0	9
Thin-bedded white chalk, somewhat nodular, about	6	0
Chalk lumps and nodules embedded in a soft grey gritty laminated marl	0	9
Hard massive chalk	2	0
Laminated marl	0	3
Massive gritty chalk, with *Inoceramus* fragments	1	0
Hard grey gritty chalk, bedded, but nodular and slightly yellowish below (*Inoceramus* bed)	4	3
Hard lumpy yellowish-white chalk, becoming pinkish in places	1	3
Hard yellowish-red rock	1	6
	22	9

The apparent dip was estimated at about 1° due north.

The outcrop of the Red Chalk can be traced across the fields south of the pit and through the wood behind Grebby Hall. Thence it runs below the village of Skendleby, and is seen in the hollow two furlongs west of Skendleby Lodge, where a strong spring breaks out and a well has been made with a ram, which pumps the water up to the Lodge.

Other springs occur at intervals along the sides of the deep and narrow valley which runs up between the hamlets of Dexthorpe and Fotherington, and the existence of which is doubtless due as much to the action of these springs as to the erosive action of rain. Another valley of similar shape and origin, but much shorter, occurs between this and Dalby Park.

The outcrop of the Red Chalk is readily traceable along the flanks of these two remarkable valleys and round the narrow ridge or promontory of Grey Chalk which separates them. The distance between the outcrops of Red Chalk on either side of this ridge south of Fotherington is only about 300 yards, though its total length from Dexthorpe to Skendleby Thorpe is a mile and a quarter. At the latter place the base of the Red Rock is visible in the banks N.W. of the Farmstead; its outcrop here makes a bold scarp facing the S.W., but on the N.E. side of the ridge it hardly produces any feature at all. From this a north-easterly dip may be inferred.

The chalk-pit at the junction of roads south of Dexthorpe is not quarried quite deep enough to touch the Red Rock, the lowest bed being probably either the topmost layer of the Inoceramus beds or the course immediately overlying them. The section seen here was as below:—

	feet.
Thin-bedded white chalk, with soft laminated marly partings, some containing rounded chalk-pebbles or nodules; three prominent bands of harder chalk occur, each about 8 inches thick	10
Thin-bedded greyish-white chalk with *Holaster subglobosus* and *Amm. varians* (compare No. 12 of Dalby section)	about 8
Hard grey chalk, with sandy marl partings	2½

In the marly bands near the top of the quarry the following fossils occurred:—*Rhynchonella Cuvieri* (abundant), *Terebratula semiglobosa*, *Inoceramus mytiloides? Vermicularia*, and the plate of *Cidaris*, sp.?

The next exposure is in a large chalk-pit half a mile N.W. of Dalby Church, where the upper half of the Red Limestone and some thickness of superincumbent white chalk may be studied.

The upper cliff was noted in detail as follows :—

		ft.	in.
Grey Chalk	Thin-bedded white chalk, with a harder band	3	0
	Band of hard white chalk	0	8
	Blocky whitish-grey chalk in thin layers	8	0
	Layer of shaly and sandy marl	0	2
	Massive greyish-white chalk (*Inoceramus latus*)	1	0
	Grey sandy shale (persistent)	0	2
Inoceramus ds.	Hard grey gritty chalk, with partings of grey sandy marl (*Inoceramus* and *Ostræa vesicularis*)	1	6
	Hard grey gritty chalk (*Inoceramus*)	2	6
	Hard grey sandy chalk with many fragments of *Inoceramus* (Inoceramus bed)	1	3
Sponge Beds	Very hard nodular yellowish-white chalk	1	6
	Thin layer of red marl (not persistent).		
	Hard yellowish-red chalk, with spongiform masses (*Spongia paradoxica*) and *Terebratula biplicata*	1	3
		21	0

An excavation in the lower part of the quarry continues the section still lower, thus :—

		ft.	in.
Red Chalk.	Hard-bedded limestone of a reddish pink when broken, but with darker red matter in the joints and cracks (many fossils, see below)	2	6
	Band of red clayey marl, with *Belemnites*	0	9
	Hard nodular red limestone, with fragments of *Inoceramus*, *Belemnites*, and *Ter. biplicata*	2	0
	Softer and more argillaceous layer	0	3
	Hard nodular red chalk (to bottom)	1	0
		6	6

The total thickness of the Red Limestone seen here is therefore between 7 and 8 feet, and more than 9 feet if the uppermost bed of yellowish chalk is included. The fossils found in the upper part are *Belemnites attenuatus*, and *minimus*, *Terebratula biplicata*, *Terebratulina ?* sp., *Avicula gryphæoides*, *Spondylus truncatus ?*

The outcrop of the Red Rock can be traced across the main road just south of the entrance to the quarry above described, and a good section of its lowermost beds was exposed in a new road-cutting made in 1881 through the hill above Dalby Church. About 8 feet of dark red chalk is here seen let down in a trough between two faults.

Large *Terebratula biplicata*, *Peeten quinquecostatus*, and *Kingena lima* were obtained from the middle of these beds.

The next locality where the beds of the Red and Grey Chalk are visible is near Langton Hall. At the corner, where the road from Langton turns eastward to Dalby Turnpike, is a pit in which some of the beds previously noted in the Dalby quarry are exposed. The following were the beds seen in 1877 :—

	ft.	in.
Whitish chalk in nodular layers	5	0
Grey sandy chalk, with *Inoceramus*	3	0
Nodular yellowish-white chalk, very hard and almost crystalline in places	1	0
Thin separation of reddish clay		—
Yellowish-red limestone, hard and nodular	2	8
Hard pink and red limestone (base not seen)	3	0
	14	8

The lower beds of the Red Rock are seen again at the top of the sand-pit about 200 yards below the chalk-pit and three quarters of a mile N.E. of Langton Church; the section at this spot has been described at p. 25, and I need only add that the thickness of the red beds shown at the north end of the pit is about 6 feet, and that their dip is about 3° to the N.E. which is much less than that of the sandstone beds. *Belemnites minimus* and *Terebratula biplicata* occurred both in the sandy marl at the base and in the nodular limestone above; a few phosphatic nodules occur in the junction beds between the Red Rock and the underlying sandstone. Viewed from a little distance the base line of the red beds appeared to be slightly undulating, but it is difficult to say whether the line of division should be drawn between the red sand and the mottled sandy clay, or below the latter. There are at any rate appearances of unconformity at this locality, though they may not be real.

At Sutterby the lowermost beds of the chalk are seen in a small pit by the road side north of the church; they were noted as follows:—

	feet.
8. Greyish white chalk, weathering into nodular forms	5
7. Greyish white chalk, with layers of grey shale	5
6. Hard grey sandy chalk in compact beds, with partings of soft sandy shale (Inoceramus Beds)	3
5. Hard greyish chalk, lumpy and nodular, becoming yellowish-white below, with sponge-like masses (Sponge Bed)	1½
Thin band of reddish clay	—
4. Hard yellowish-pink rock, broken and blocky	1
3. Nodular pink rock, the interstices between the lumps being filled with red argillaceous matter	5
2. Dark red rock with layers of red shaly clay, becoming more argillaceous below, and passing down into No. 1	5
1. Red sandy clay, containing small grains of quartz, lydian stone, &c., and numerous *Belemnites*	2
	27½

The fossils collected by Mr. Allen and myself from these beds are given below:—

From Nos. 7 and 8. *Holaster subglobosus, Discoidea cylindrica, Ostrea vesicularis, Inoceramus sp., Terebratula semiglobosa, Ter. biplicata, Serpula* sp., *Rhynchonella Cuvieri.*

From No. 6. *Ammonites varians, Turrilites* sp., (*? tuberculatus*), *Ostrea vesicularis, Inoceramus latus, Anomia?, Terebratula semiglobosa, Ter. biplicata, Discoidea cylindrica.*

From Nos. 4 and 5. *Avicula gryphæoides, Terebratula biplicata, Inoceramus* sp., *Spongia* sp.

From Nos. 2 and 3. *Belemnites minimus, Ostrea vesicularis, Plicatula minima, Avicula gryphæoides, Inoceramus tenuis, Terebratula biplicata, Ter. capillata, Ter. semiglobosa, var. undata.*

From No. 1. *Belemnites minimus, Terebratula biplicata*, and *Ter. capillata.*

The lowermost beds are seen at the entrance to the small sand-pit mentioned on p. 26., and present the appearance of being banked against the Carstone.

Whether this is the result of an actual unconformity, or has been caused by a slight landslip or by a fault is difficult to say. When I first visited the spot I thought it was a case of unconformity, but a second inspection inclined me to think Professor Judd was right in regarding it as a fault. A smaller fault with about 6 feet throw and striking from S.W. to N.E. crosses the road above, and it is probable therefore that the Froghall fault extends to this spot. Mr. Strahan also subsequently visited the section and concurs in this view.

From Sutterby the boundary of the Chalk strikes nearly due east to the bold bluff of Harrington Hill. Here its basement beds are seen crossing the

road above the outcrop of the brown sands, and again in a chalk quarry on the north side of the road about half a mile S.S.W. of Brinkhill; the red beds are just touched at the north corner of the pit, and they are said to be 12 feet thick in a well at the cottage (Appendix, p. 151). The southern face of the pit shows only 12 to 15 feet of nodular grey chalk, with partings of grey shaly marl. The fossils found here are given in Appendix, p. 143.

South of Driby the irregular line formed by the boundary of the Chalk has been produced by the action of the numerous springs which burst out from its base, and each of which is situated at the extremity of a little combe or valley of its own making. The boundary may be readily traced by means of these springs and by the colour imparted to the soil at the outcrop of the Red Limestone. It is remarkable that the boundary of the Chalk on the south side of this spur is much less indented than that on the northern side; neither are any springs thrown out, so that the existence of a northerly dip here may be inferred, due probably to a slight undulation of the strata at right angles to the general line of strike, for if the beds forming the hill are slightly tilted up to the south, the strongest springs would naturally be thrown out on the northern slope.

Near Driby Grange the outcrop of the Red Chalk is cut off by a fault striking N.W. and S.E., and bringing the Gray Chalk into contact with the "roach" and the Tealby clay. No sections occur near Driby, and except in the outlier near Ormsby the basement beds are not seen again till we come to the neighbourhood of Holster Dale, near Worlaby. This dale is another of the deep recesses which have been eroded out of the scarp edge by the action of rain and springs.

The Red Rock and overlying grey beds are seen in some old pits three quarters of a mile south of Worlaby, and again in another pit about the same distance S.S.W. of Worlaby; in the latter about 8 feet of Red and 14 feet of Grey Chalk are shown, but their relations are obscured by talus.

The quarries near Tetford Wood are in the higher part of the Lower Chalk, and will be mentioned hereafter.

The section of Red Chalk and Carstone at Tithe Farm, near Belchford, has already been described (see p. 26).

"The Red Chalk is also seen in a kiln about a mile north-west of Tithe Farm, but the section is not sufficiently complete to be worth more than a mention. Northwards it is easily traceable by the fragments in the soil, but no exposures were found." (Note by A. Strahan.)

Behind the Farm, three-quarters of a mile north of Gaumer Hill, a small quarry is dug in the Grey Chalk, showing:—

	feet.
Thin-bedded chalk weathering into nodular lumps - -	12
Band of yellowish shale - - - - - -	
Nodular greyish chalk - - - - - - -	2
Compact grey chalk, with looser and nodular grey chalk below (*Holaster subglobosus*) - - - -	4
Nodular pink chalk (top of Red rock) - - - -	2
	20

Outliers.

The only outlier of any importance is that near South Ormsby, and in this the only exposure seen was a chalk pit three-quarters of a mile W.S.W. of South Ormsby, by road to Cloven Hill Farm. The entrance passes through the outcrop of the Red Rock, but the section is overgrown.

At the east end where recently quarried (1880), the Red Rock is brought up by a fault, from which the beds plunge down to the south at an angle of about 35°.

Descending succession as follows:—

	feet.
Chalk rubble and broken nodular grey chalk - -	6
Hard grey sandy chalk (*Inoceramus* beds) - - -	3
Grey nodular chalk, becoming yellow at base - -	2½
Red rock, top beds - - - - - -	2
	13½

The beds appear to recover from this local dip towards the south, and their outcrop forms a nearly straight scarp along the south-eastern edge of this outlier.

The small outliers which cap the high ground north-west of Brinkhill, and the long narrow ridge which cap the long narrow ridge which runs from Cloven Hill to Warden Hill consist mainly of the Red Chalk, with a thin covering of the Grey Chalk in places.

The outliers at Tetford Parsonage Hill, on the hill north of Belchford, and at Gaumer Hill, have already been mentioned (see pp. 21 and 27.)

Inliers.

The valley which debouches near Claxby coincides with a line of fault, the throw of which is very considerable; so much so that the Red Rock and the underlying sand are brought to the surface for some distance along the upthrow or S.W. side; numerous small transverse faults, however, interfere with the line of outcrop, and prevent the exposure from being a continuous one.

The base of the Red Rock was seen in a small excavation at the back of the cottage 1 furlong S.S.W. of Claxby Church; brown sand was exposed below, but did not appear to be very thick, as yellow and blue clay was found near the bottom of the garden. Below the Churchyard on the opposite side of the valley white chalk is seen, and the well at the Rectory above is said to be 81 feet deep without piercing the chalk, so that the throw of the fault here can hardly be less than 50 or 60 feet.

West of the Church, by the side of the road crossing the valley, there is a strong spring issuing from several apertures at the base of a vertical chalk cliff about 20 feet high. The beds consist of hard nodular rocky chalk, one course of which, about 6 feet from the bottom, is slightly tinged with pink, but the Red Rock is not exposed here. The dip of the strata, judging from the inclination of the marly layers between the bedding planes, is a low one to the S.W.

This spring is not on the main line of fault, but 50 or 60 yards to the S.W. of it, and may be due to a transverse fault coinciding with the valley which here comes in from the west. It appears probable indeed that there are two such faults, parallel to one another, and letting down a trough of white chalk between them, so that the outcrop of the Red Rock is here below the level of the valley bottom.

Proceeding up the valley fragments of Red Chalk were found on its S.W. slope, but no exposure of it was visible. About a quarter of a mile beyond the spring the valley changes its direction, and runs nearly due west, and the Red Rock crops out near the bottom of the valley on the south side the road as far as the cottage on Mr. Higgins' farm, where a well has been sunk through chalk rubble and sandstone into clay.

It is then thrown up to a higher level by a transverse fault, and its outcrop forms a steep scarp for some distance along the southern flank of the valley, contrasting strongly with the even and gentle slope of white

chalk along the northern side. At the commencement of this steep bank sand has been dug out, and the following section is visible:—

		feet.
Red Chalk.	Rubble of white chalk	2
	Yellowish pink chalk, passing down into lumpy red chalk, with *Avicula gryphæoides*	5?
	Dark red rock, becoming argillaceous below and passing into a red clay, containing *Belemnites minimus* in abundance, also *Terebratula biplicata* and *Ostrea vesicularis*	6
	Green sandy clay, yellowish at the top, and not separated very distinctly from the bed above	2
	Coarse brown sand	3+
		18

The dip of these beds appears to be to the S.W. at about 3°, but in passing westward along the outcrop this dip is altered by several minor faults, which are too small for insertion on the map, and the general dip must be southward.

At Skendleby Salter there is another transverse fault, and Red Rock is found on both sides of the road, but its outcrop on the south side is higher than that on the north; it may be seen in the bank below Mr. Belton's house. The only explanation of these facts appears to be that of a broken anticlinal along which the valley has been excavated, but in following the two outcrops of the Red Rock westward, they are found to terminate suddenly, and are evidently cut off by another transverse fault parallel to the last; so that the phenomena to be accounted for here are very complicated.

There can be little doubt, however, that the main line of fault is prolonged up the valley to Ulceby, and is connected ultimately with the fault of the Driby Valley.

A small inlier of the Red Rock and underlying sandstone occurs between Calceby and Swaby, probably brought up by a fault, but it is so hidden by Boulder Clay and gravel that the outcrops cannot be followed. Red Chalk was seen about five furlongs south of Swaby in the gully of the stream, and again about three-quarters of a mile S.W. of Swaby. It also appears to underlie the Boulder Clay at Ketsby Mill.

A much larger and more important inlier, occupying an irregular space near the villages of Worlaby, Ruckland, Farforth, and Oxcombe, has been mentioned already in connexion with the Neocomian beds (p.). The general dip of the beds here being to the north-east, numerous strong springs are thrown out along the western and southern slopes of this inlier at or near the outcrop of the Red Chalk: the recession of the principal spring heads has produced the remarkably indented boundaries seen on the map, which contrast with the more regular boundary along the northern border of the inlier, where the Red Rock dips inward under the Grey Chalk.

The Red Chalk is seen in many small exposures round the inlier, but the only good section is that in a quarry on the spur of the hill west of Oxcombe. The beds here exposed in 1881 were:—

	feet.
Chalky soil	1
Grey nodular chalk, broken and weathered	5
Dirty or dull yellow chalk	0½
Light pink chalk, yellowish in places	1½
Persistent layer of dark red clay	—
Dark red rock with layers of still darker red marl or clay (base not seen)	6
	14

The small inlying exposure of the basement beds, brought up by a fault half a mile S.W. of Withcall Church, has already been mentioned (p. 27).

There are also reasons for believing that a larger inlier of the same beds occurs near Hallington and Raithby, but is concealed by the Boulder Clay which occupies the bottom of the valleys. In the road-cutting below the chalk pit at Hallington fragments of red chalk were observed in the bank, but whether these marked the outcrop of the basement rock, or of the lower pink bed faulted down could not be determined. At the spring head east of the farm called Maltby there are many pieces of hard red chalk, and some containing *Belemnites*, so that there is little doubt of the basement bed being here exposed beneath the Drift, and a section across the valley would resemble the following:—

FIG. 6.

Section across the Valley near Hallington.

Scale six inches to a mile.

h Newer Boulder Clay. *c* Red Chalk.
e Band of Pink Chalk. *b* Carstone.
d Grey Chalk. *a* Tealby Clay.

At Tathwell there are strong springs thrown out at the base of a cliff of greyish-white chalk, and the red rock cannot be far below. It was pierced in a well at Tathwell Hall (see Appendix B, p. 172). At the farm called Dovendale, one mile west of Tathwell, it was found in a well at a depth of about 15 feet beneath Boulder Clay (Appendix, p. 153); and I saw the brown sand and red marl with *Belemnites* which had been thrown out from the bottom of this well.

§ 2. UPPER BEDS OF GREY CHALK.

Pursuing the plan indicated on p. 43 the following notes are descriptive of the upper beds of the *Holaster subglobosus* zone, or those which contain the pink courses so conspicuous at Louth; commencing as before at the south end of the Wolds.

The chalk pit half a mile west of Welton Church exposes beds which belong either to this zone or to the overlying part of the chalk without flints; the section is as follows:—

	feet.
Chalky soil and rubble - - - - - -	3
Hard chalk in thin beds separated by marly partings, surface of beds nodular and uneven - - - - -	10
Course of hard chalk between two layers of grey clay -	1
Very hard rocky chalk, greyish-white, and indistinctly bedded - - - - - - -	4
	18

The apparent dip as seen along the north face is westerly about 5°. Several small faults occur and slickensides are frequent. There is no sign of any pink bed, and no means of determining the exact horizon. The fossils found were *Inoceramus mytiloides?*, *Ostrea acutirostris*, *O. vesicularis*, *Exogyra* sp., *Terebratula biplicata*, and *Goniaster* sp.

In Welton Wood, about a mile N. of the East and three furlongs N.W. of Thwaite Hall, is another pit, and some of the beds here seen must belong to the zone of *Holaster subglobosus*. They are much faulted, and the most

complete section as seen about the middle of the western face of the quarry is as follows :—

	feet.
Soil and chalk rubble	2
Rather hard thin-bedded chalk	15
Hard grey chalk	3
Layer of grey laminated marl	—
Loose rubbly greyish chalk, with two distinct layers of yellowish marl, one at top and one in the middle	6
Hard grey chalk, in thick beds and falling in large blocks	7
	33

The beds here dip at about 15° to the S.W., but N. of this there is a double fault, with downthrow to the N.E., of 16 feet (12 feet in the first slip and 4 feet in the second). Beyond this the dip is less, but there seem to be other small faults, and at the northern corner the chalk with layers of marl is faulted against beds of bluish-grey chalk, which are nearly horizontal.

The grey chalk is also exposed at the bottom of the large chalk pit at Claxby (see p. 61).

Two old quarries, one east and the other north-east of Skendleby, may possibly be in this part of the zone; and there is a newly opened pit about half a mile S.E. of Ulceby Church which appears to be in the central or higher beds. When seen in 1880 it was only 7 feet deep, and exposed beds of nodular grey chalk, with a layer of grey shaly marl; the upper beds contain *Holaster subglobosus*, *Rhynchonella Cuvieri*, and *Terebratula semiglobosa*. Mr. Rhodes subsequently found *Ammonites peramplus* here.

No other exposures occur for some distance, but near Driby, on the by-road to Manor Farm, beds of pink chalk were seen below the hedge on the N.W. side, and the uppermost of them is seen in the pit half a mile W.S.W. of Calceby (see p. 62).

The first good section of these beds, however, is in the large quarries at South Thoresby, two furlongs N.W. of the Church. At the N.E. corner of the quarry, where the lowest beds are excavated, the following measurements were taken :—

	feet.
Broken rubbly chalk	1
Pale pinkish-white chalk, in one massive course	2
Hard but brittle yellowish-pink chalk, in even beds about a foot thick	7
Layer of dark grey clay	—
Greyish-white chalk in thin beds, with partings of argillaceous matter	6
Compact grey chalk in two courses, the hardest and toughest of all	4
Layer of grey shale	—
Hard cream-coloured chalk in thin beds	4
Thin layer of soft yellowish marl	—
Reddish marly chalk, indistinctly bedded, pink and brick-red above, with a band of chocolate-red marl in the middle, pink with grey lumps below	6
Layer of grey laminated clay, about 1½ inches	—
Hard grey gritty chalk in thick beds, the topmost being nodular and broken (a large Ammonite seen here)	4
Layer of laminated marl	—
Hard grey chalk, with nodular crystalline lumps	3
	37

These beds are broken by a fault with an upthrow of about 6 feet on the southern side. Higher beds are seen in the middle of the quarry face,

and will be described in the next Chapter (see p. 62). The band of mottled red-green and grey marl there mentioned immediately overlying the topmost bed in the section given above.

Another pit at the fork of the roads north of the last shows about 12 feet of hard grey nodular chalk; these are at a lower level than the base of the large quarry, and the workmen say they have dug 20 feet lower than the floor of this pit without reaching anything different.

A small pit in deep valley, five furlongs N.E. of Swaby Church, exposes some of the same series, as below:—

	feet.
Hard and nodular grey gritty chalk, with thin bands of grey shale	12
Very hard nodular yellowish chalk	1½
Yellowish-red rock, hard and lumpy, with layer of dark red clay at base	2½
Brick-red rock, more definitely bedded	4
	20

The dip is about 3° to the N., but a small fault throws the beds up about 3 feet on the E. side.

The topmost beds are full of *Inoceramus*, and the red chalk is probably the lower of the two red beds at Thoresby.

The chalk-pit, one mile N.N.W. of Swaby, shows grey chalk dipping about 2° to the N.E., the beds belonging probably to the middle part of the Lower Chalk (below the red bands) brought up in the centre of the anticlinal:—

	feet.
Rubble, with pieces of pink chalk	2
Greyish white chalk	3
Beds of grey shaly chalk	1½
Hard massive bed	1
Thin-bedded chalk, with shaly layers, partly concealed by talus (*Inoceramus* and *Lima echinata*)	12
About	20

The beds probably roll over and dip to the S.W. on the western side of the valley, and pink chalk is seen cropping out along the flank of the curious gulley marked on the map.

The quarry at White Pit Houses west of Swaby (*see* Fig 9, p. 63) shows the topmost bed of pink chalk and its junction with the overlying zone, and another pit, two furlongs south of Ketsby Mill, shows a band of pink chalk, dipping 5° to S.E., but much broken and faulted:—

	feet.
Loose rubbly grey chalk	1
Pinkish chalk, becoming grey and rubbly below, with a thin layer of grey marl at the base	5
Hard massive grey chalk, very nodular in the upper 18 inches (*Discoidea cylindrica*)	6

This pit is opened in a ridge which forms a very peculiar feature, running for some distance between two troughs which curve round the hill side and open out into the Ormsby Valley. They present the appearance of artificial trenches, but the section above noted shows that the intervening ridge is not artificial; if they have ever been occupied by watercourses it must have been before the present system of drainage.

Pink beds are seen in the road ascending the hill north of Ormsby Park,

and a chalk pit, by the side of the same road, half a mile S.E. of Ketsby Farm, shows the following:—

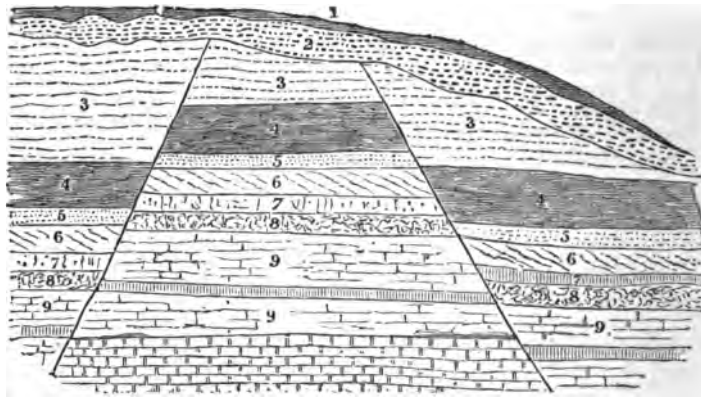
	feet.
6. Soil, with band of grey, red and purple marl below in one part of the pit	1½
5. Hard cream-white chalk	5
4. Loose yellowish-grey chalk	3
3. Hard cream-white course	1
2. Shaly yellowish-pink chalk	1
1. Hard greyish-white chalk	4
Talus	10
	25

The beds are broken up by small slips and faults, but there is a general dip of about 6° to the S.S.W. The beds numbered 2, 3, and 4 are on the horizon of the upper pink band at South Thoresby, which is here more of a yellowish colour. The overlying layer of variegated marl is identical with that exposed at South Thoresby and elsewhere.

Near Tetford Wood there are large quarries on either side of the road; those on the west side have been long disused, that on the east side exposes a good section of the Grey Chalk, including the lower pink band, which seems to have a wider extension than the upper. Fig. 7 represents this section as drawn by Professor J. W. Judd, in 1866, and lent by the Council of the Geological Society;* the description below being slightly altered in accordance with notes taken by myself in 1881:—

FIG. 7.

Section in a Chalk-pit by Tetford Wood.



	ft.	in.
1, 2. Soil and chalk rubble	2 to 3	0
3. Greyish-white chalk in thin beds, rather broken	10	0
4, 5. Pale pink chalk, with soft marly layers, and a whitish band at the base	5	6
6. Hard nodular grey chalk	2	0
7. Grey sandy chalk ("drab bed")	1	6
8. Greyish nodular chalk ("knobbly white bed")	2	0
9. Greyish white chalk, evenly bedded, including a course of hard compact chalk which rings under the hammer and known as "pot-chalk"	12	0
10. Nodular grey chalk in regular beds	3	0
	38	0

* Quart. Journ. Geol. Soc., vol. xxiii., p. 246.

Professor Judd was informed that the workmen had bored about 30 feet lower in the same nodular chalk.

Returning now to the neighbourhood of Burwell, the pink beds are seen in an old pit by the road side half a mile south of the Hall, and the upper beds are well shown in a larger quarry about three furlongs E.S.E. of Burwell Hall. At the N.E. end of this the following section was taken:—

		feet.
Glacial.	Boulder Clay, thin edge in pockets	2 to 3
	Chalky gravel, pebbles mostly chalk, but some flints	2
Middle Chalk.	Hard chalk, grey and nodular, in regular beds	8
	Band of mottled marl, purple and green, with nodules of hard chalk in lower part	1½
Lower Chalk.	Yellowish-pink chalk	3
	Very hard yellowish-white chalk, in one massive bed	1
	Pink chalk, brittle and breaking in flakes	6
	Hard cream-white rock	1
	Greenish-grey shaly chalk	1
		25

These beds may be compared with the upper part of the Thoresby pit. Several small faults occur, but a general dip to the W. is observable.

The grey beds below these are seen in a small pit three furlongs west of the Hall near the Park gate, and again in an unused pit five furlongs N.N.W. of Burwell Church.

The road cutting N.E. of Tathwell shows pink shaly chalk, overlain by grey chalk, with seams of shaly marl.

Near Raithby a pit three furlongs W. of Church shows:—

		ft.	in.
Middle Chalk.	Soil and chalk rubble	3	0
	Grey shaly marl, with layer of purplish marl at base, enclosing rolled lumps of hard chalk	1	3
Lower Chalk.	Cream-white chalk in thin beds (*Inoceramus*)	9	0
	Yellowish-pink chalk, with shaly partings	1	3
	Hard grey chalk in thick beds, with partings of grey shale, dipping to N.W. (containing *Ammonites peramplus* and other fossils, found by Mr. Rhodes)	10	0
		24	6

The railway cutting west of Withcall Station shows Lower Chalk, with a pink band near the middle, dipping westward, but broken by a succession of small faults with down-throws on the western side, so that the beds are continually thrown up to the east. The section in the centre of the cutting, and measured roughly by the eye only, was:—

	feet.
Greyish-white chalk in thin beds, up to	15
Light pink chalk	5
Harder grey nodular chalk	12

At Hallington there is a clearer and more accessible section in a quarry north of the Farm. The beds seen here are:—

	feet.
Soil	1
Whitish chalk, with *Terebratula biplicata*	4
Pale pink and yellowish chalk, soft and shaly, but enclosing harder lumps of grey chalk (*Holaster subglobosus*, *Terebratula biplicata*, *T. semiglobosa*, &c.)	5
Broken white platy chalk, passing down into shale, with loose nodules	2
Hard rocky nodular chalk (*Ammonites rhotomagensis* and *Pecten orbicularis*)	2
Hard grey chalk, open jointed and breaking into blocks	1¾
Grey nodular chalk, with yellow stains, and layer of shale at the base; a few fossils	2¼
Whitish chalk in thin beds, with shaly layers	7
Hard grey compact limestone in massive beds	5
	30

Two small faults make a small trough in the middle of the pit, and the dip appears to be to the N.N.E. The pink chalk here is identical with the lower of the two beds seen near Louth, where, however, the shaly chalk below is also coloured pink (*see* p. 58).

Another good section of these beds occurs in the valley north of Hubbard's Hill, and opposite the Louth Waterworks:—

	feet.
Soil	1
Broken greyish chalk	3
Yellowish-pink chalk, with a band of darker pink at the base	6
Hard greyish chalk, with layers of grey shale	10
Hard grey chalk in thicker beds	8
Light red chalk, yellowish in places, with nodular lumps of hard whitish chalk; the lower portion consists of red marly chalk, with a basement layer of grey shaly marl (*Holaster subglobosus* and other fossils)	5½
Grey nodular chalk, with shaly partings	2½
Hard grey chalk in massive blocks (fossils)	8
About	44*

A strong fault cuts through these beds, striking E.N.E. and W.S.W., and throwing them down about 5 feet. On the north-west side the cutting by the side of the road beyond this section shows a succession of small parallel faults, made evident by the dislocation of the pink course; at one point this is thrown down below the roadway, but is faulted up again to the same level about 50 yards farther on: it is again faulted down about 6 feet, and finally crops out to the surface near the farm buildings where the road turns eastward. In the grey beds below I found a large specimen of *Ammonites peramplus*; this is the same horizon at which *Ammonites rhotomagensis* occurs at Hallington and another large Ammonite at South Thoresby. Elsewhere I have also found fragments of large Ammonites, always about the same distance below the lower land of pink chalk.

* Between the base of this section and the level of the ground at the Waterworks (*see* Appendix p. 160) there is a fall of 14 feet.

South of Louth, and on the east side of the London Road, are two large chalk quarries, the northernmost of which, belonging to Mr. W. Larder, exposes a good section of the Grey Chalk, as given below:—

		feet.
Middle Chalk.	White chalk with layers of flints - about	15
	Yellowish-white chalk in regular beds, with *Rhynchonella Cuvieri* and *Inoceramus mytiloides*, about - - - -	12
	Soft marly clay or "fuller's earth," bluish-grey, variegated with red, and containing loose nodules of hard chalk at the base	1½
Lower Chalk.	Hard yellowish-pink chalk, resting on a layer of red clay - - - -	1½
	Hard yellow rocky chalk for 3 feet, passing into yellowish-pink chalk, the lowest foot soft and shaly - - - -	8
	Hard greyish-white chalk with thin seams of grey shale. (*Discoidea cylindrica, Holaster trecensis, Rhynchonella Cuvieri, Terebratula biplicata, Ter. semiglobosa*, and *Ostrea vesicularis*) - - - -	12
	Very hard grey rock, in large blocks fit for building purposes (seen in lowest part of pit) - - - - -	4

The workmen state that below this they find—

Nodular grey chalk, in thin beds - - - -	3
Dark red chalk - - - - - -	7

A well was sunk 24 feet lower still through beds of grey chalk and finding water at that depth.

These statements and measurements differ somewhat from those given by Professor Judd in 1867.* I did not find that the nodular base of the "fuller's earth" graduated into the underlying chalk; on the contrary, it seemed to me sharply defined. The foreman, whom I saw in 1882, mentioned only one course of red chalk as occurring beneath the quarry-floor, and his statements are confirmed by the sections on the north side of the town, where this lower red bed with some 16 feet of grey chalk below are exposed to view. Neither have I found a third course of red chalk anywhere else in the position indicated on Professor Judd's vertical section. A thin bed of red marl is mentioned in the boring at the water-works (*see* p. 160), but this is about 36 feet lower down. I cannot but conclude therefore that he was mistaken in thinking the workmen whom he interrogated meant to describe two separate courses of red chalk, each of the same thickness; and that they really referred to one and the same course. Lastly, I must point out that the thickness of grey chalk intervening between the upper and lower pink courses is only about 20 feet and not more than 30 as stated by Professor Judd.

On the north side of Louth, where the word "lime-kilns" is marked on the map west of the Union-house, there are two large quarries adjoining one another, which afford a very complete section of this part of the chalk. In the southernmost at the road corner, and belonging to Mr. Clapham, the following beds were seen in 1882:—

	ft.	in.
Soil (a foot), underlain by brown loamy clay with small stones (Hessle Clay) - - - - -	6	0
Chalk rubble in soft grey clay - - - -	1	0

* Quart. Journ. Geol. Soc., vol. xxiii., p. 239.

	ft.	in.
Yellowish-pink chalk, hard, but broken up at the top, soft and platy below	8	0
Greyish-white chalk in thin beds, rather hard, with thin layers of marl	11	0
Hard nodular massive chalk, forming one massive bed; this has been used for building	4	0
Nodular grey chalk, loose and easily broken	3	0
Thin seam of grey marly clay		—
Pink and grey chalk, passing down into reddish chalk with lumps of grey, and seams of red marl in the middle	7	0
Hard nodular grey chalk	2	9
Compact grey chalk, gritty or sandy, very hard and dark grey when wet (resembles the Inoceramus bed)	1	7
Hard nodular grey chalk, becoming platy below	2	6
Parting of grey shale, 1 to 2 inches		—
Grey chalk in thick beds with partings of shale, not nodular, but breaking into lenticular plates	10	0
About	57	0

The workmen state that the same grey chalk is found below the present floor until water is met with. From the grey beds at the base Mr. Rhodes obtained many fossils (see Appendix, p. 144).

The second pit belonging to Mr. Paddison carries the section higher than the first; measurements here give:—

		ft.	in.
Glacial.	Red-brown Boulder Clay from 8 to	10	0
	Rubble of clay, sand and chalk	2	0
Middle Chalk.	Broken chalk, with flints	2	0
	Hard yellowish-white chalk, in layers about a foot thick, with shaly partings	10	0
	Buff, gritty, marly chalk, full of Inoceramus shells	0	6
	Hard whitish chalk in even beds	3	0
	Soft grey and buff marls,* enclosing a band of marly chalk, and containing nodules of hard chalk at the base	2	6
Grey Chalk.	Hard white chalk ("the white course"), resting on a thin seam of red marl	2	0
	Hard pinkish-white in thick even beds, pinker below, and resting on a base of pink and yellow marly chalk	7	6
	Greyish-white chalk, stained pink at the top, weathering into flat irregular plates or lenses	12	0
	Hard grey limestone	4	0
	Hard grey nodular chalk	3	0
	Pinkish-grey chalk, passing down into light red chalk, forming lowest floor, seen for	4	0
		62	6

The lower pink chalk is identical with the 7-foot course seen in the last section. The uppermost pink course is seen again in a chalk-pit in

* From these Mr. Rhodes obtained *Terebratula biplicata* and *Ostrea vesicularis*.

Elkington Pasture, see p. 65; and also in a small quarry on the north side of the main road, about three-quarters of a mile S.S.E. of South Elkington. Here the variegated marl band which overlies the Grey Chalk just comes in at the top of the pit, the section being as below :—

	feet.
Chalky soil	1
Marly chalk, with a band of grey marl, and a thin seam of purple marl	2
Creamy-white chalk, marly above but massive below, rather brittle	4
Yellowish-pink chalk, with hard courses in the middle, separated by reddish marly bands	6
Loose shaly red and yellow marl, forming base of above	1
Greyish-white chalk in thin beds, with shaly partings	7
	21

The next exposure is an old pit behind the lodge at the entrance to Welton Vale, about half a mile west of the above. Here the lower band of pink chalk is seen near the top; the succession being :—

	ft.	in.
Chalky soil	3	0
Pink and white marly chalk	3	0
Soft white lumpy chalk in two layers, with yellowish marl at the base	1	6
Rough nodular grey chalk	3	0
Hard massive grey rock (with *Ammonites*)	1	6
Nodular grey chalk	2	6
Thick-bedded greyish-white chalk	2	0

The beds below are hidden by talus.

CHAPTER VI.

MIDDLE CHALK.

Description of Sections.

A general description of the beds included in this division has been given at p. 37, and we now give the details upon which it was founded, commencing in the case of each zone with the localities at the south end of the Wolds and working northwards.

§ 1. Zone of Inoceramus mytiloides.

If the beds seen in the pit near Welton, described on p. 51, be rightly referred to the Grey Chalk, the first section in the overlying is a pit near Thwaite Hall, about three-quarters of a mile N.W. of Welton; this exposes the junction of the white flinty chalk with the flintless chalk, as below:—

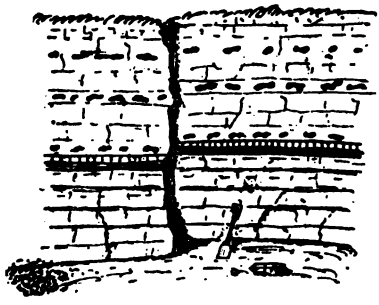
		feet.
Zone of *Ino. Brong.*	Soil and rubbly chalk	3
	Chalk, with grey flints, in thin beds about 6 inches thick, partly obscured by talus	12
	Hard white crystalline chalk, with vertical jointing	0½
Zone of *Ino. myt.*	Rubbly beds, consisting of hard chalk lumps, with grey marl in the interstices	0½
	Hard chalk in beds from 6 to 9 inches thick	5
	Grey fissile chalk with shaly layers	3
		24

The beds have a strong dip to the S.W., the angle being about 15°.

A similar section is seen in the pit at the N.W. corner of Orby Wood, and three-quarters of a mile S. of Claxby Church—

Fig. 8.

Section in a Chalk-pit south of Claxby.



	feet.
Crumbling white chalk, with three lines of flint nodules, one being at the base	12
Hard white chalk, jointed vertically and breaking in a roughly columnar fashion	0½
Grey fissile platy chalk	0½
Greyish-white chalk without flints, in beds 6 to 9 inches thick, with marly partings	7 to 8

These beds dip to the S.S.W. at 5°, and consequently the lower beds crop out a short distance east of the pit. The lowermost layer of flints separate easily from the matrix, but those in the second layer crack in the same plane with the joints of the chalk as if these were prolonged through them as lines of weakness, so that portions of these flints remain embedded in the matrix while the rest of the nodule comes away in the fallen chalk.

A more complete section is found in the chalk-pit N.W. of Claxby Church. This is a large quarry about 200 yards long and more than 30 feet deep at the north-west end where the junction of the Lower and Middle Chalk is exposed. A fault is found to strike through the pit from W.N.W. to E.S.E., and is seen in section at the north end where the vertical displacement is about 10 feet, with the downthrow to the N.E., as in the parallel fault of the Claxby Valley.

The following section was taken on the east side of this fault in November 1879:—

		feet.
Zone of *Ino. Brong.*	Soil and chalk rubble	3
	Hard creamy-white chalk, with a line of large nodules of grey flint, and a thin layer of continuous flint near the base	13
	White chalk, loose and jointed, with a basement layer of grey marl (= the *columnar bed*)	0½
Zone of *Ino. myt.*	Very hard grey chalk, in beds a foot thick or more, with partings of grey marl	8
	Layer of loose grey marl, with small nodules of hard chalk, fragments of *Inoceramus* and *Terebratula semiglobosa*	0½
	Greyish-white chalk in two beds (not very hard)	2
Loose grey marl, full of nodules of hard crystalline chalk, with a yellowish coating		1
Hard grey chalk in thick beds (*Discoidea cylindrica*, &c.)		6
		34

A little eastward of this there is a second smaller fault, with downthrow to the N.E. as before, and bringing in another 6 feet of hard white chalk with flint nodules; in this good specimens of *Terebratula semiglobosa* are abundant. These beds are nearly horizontal, but near the larger fault they dip westward at 3 or 4 degrees.

On the west side of the fault the marl bed with yellow nodules can be distinguished at a height of about 15 feet from the floor of the pit, and can be traced at intervals all along the west side of the quarry; it is evidently identical with the mottled grey and purple marl of the sections near Louth.

The lowermost beds consist of greyish-white, splintery and free-working chalk; according to the foreman they burn to a softer and better lime than those above the nodule bed, which are rough and nodular on weathered faces.

These lower beds and their junction with the overlying white chalk are exposed at the bottom of the pit a quarter of a mile west of Ulceby Church (see p. 52), and again in the pit three furlongs N.W. of Driby High Barn, where the section is as follows:—

		feet.
Zone of *Ino. Brong.*	Soil and chalk rubble	1 to 2
	Hard white chalk, with layers of flint nodules	3 to 6
	Compact white chalk, brittle, and vertically jointed-junction bed	0½
Zone of *Ino. myt.*	Layer of greyish shaly marl with loose chalk nodules of a yellowish colour	0½
	Grey chalk, irregularly bedded, rather hard and gritty, and weathering into flattish lumps	6

The height of the pit face is not more than 10 feet and the beds are nearly horizontal, but they are thrown down to the east by a fault with a fall of about 3 feet, which brings in more of the chalk with flints.

A more complete section is found in another quarry nearly and about half a mile S.E. of Calceby Church, as below—

		feet.
Brown sandy soil		1
Zone of *Ino. Brong.*	Broken chalk, with a layer of flints at base	4
	Hard massive white chalk, in thick beds, with nodules of grey flint near base	5
Zone of *Ino. myt.*	Grey laminated marly chalk	0½
	Hard greyish chalk in thick beds, without any flints, weathering yellowish-grey	9½
Dull red laminated marl, and red laminated marly clay		1½
Rubbly layer containing nodules of yellowish chalk		0½
Very hard cream-coloured chalk, becoming pink below (compare section at South Thoresby)		2
		24

These beds have a dip of 4 or 5 degrees to the S.W.

A small pit, barely a quarter of a mile W.S.W. of Haugh Church, is dug in thin-bedded yellowish chalk, hard and gritty, with numerous fragments of *Inoceramus*.

The large quarry and lime kiln at South Thoresby has already been partially described (p. 52); along the south-east face of this pit the beds dip to the S.W., and the dip increased towards the centre of the south face till it reaches an angle of 24°, bringing the base of the chalk with flints below the surface of the ground. The whole series is then broken and thrown up to the westward by two faults, with displacements of about 8 and 6 feet respectively. The succession here as measured in 1879 is given below—

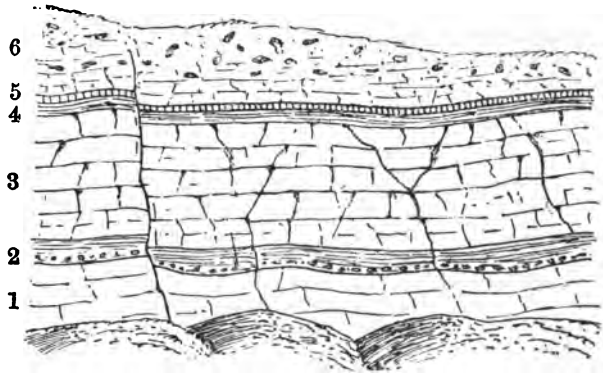
	feet.
White chalk, with flints	0 to 5
Layer of closely-jointed white chalk ("columnar bed")	0½
Layer of loose rubbly shale	0½
Beds of hard greyish chalk, with a yellowish tinge, very gritty, and containing numerous fragments of *Inoceramus*	12
Conspicuous band of variegated marl, in three layers, each about 6 inches thick, the highest is a yellowish laminated marl, the second is grey lumpy chalk, the lowest is mottled, red, buff, and green	1½
Hard pinkish-white chalk	3
Yellowish-pink chalk (see ante p. 52)	7
	29

In the west corner under the road there are several smaller faults, some of which hade in opposite directions and produce small troughs, the chalk between them being much broken and crushed.

The upper beds of the chalk without flints are also well shown in a chalk-pit half a mile W.N.W. of Swaby Church.

FIG. 9.

Sketch in a Chalk-pit near Swaby.



	feet.
6. Broken chalk rubble, with flints - - -	0 to 4
5. Columnar bed - - - - - -	0½
4. Grey shaly chalk - - - - -	1
3. Hard nodular grey chalk in massive beds, about 18 inches thick - - - - -	10
2. Pink shaly chalk, passing down into mottled purple and grey marl, which contains loose nodules of hard chalk, and seems to rest unevenly on No. 1 - -	3
1. Hard pink chalk, seen to depth of - - -	4
	22

There are several small slips, but the general dip seems to be about 7° to the West. Fig. 9 represents the appearance of the beds above noted.

The line of junction between this zone and the overlying chalk with flints is also intersected in an old quarry seven furlongs W.N.W. of Belleau, the following beds being visible:—

		feet.
Zone of *Ino. Brong.*	Clayey soil and chalk rubble - - - -	2
	Cream-white chalk, with flints - - - -	5
	Columnar (junction) bed, well weathered - - -	0½
Zone of *Ino. myt.*	Layers of grey shale, with hard chalk between - -	0½
	Hard greyish chalk in massive and regular beds - -	5
	Talus, hiding the lower beds.	

These lower beds, including 8 feet of hard greyish chalk full of *Inoceramus*, resting on the variegated marl band, are seen in a pit three-quarters of a mile to the northward of the last; the section has been given previously (see p. 55).

Another exposure occurs in a small pit by the road side half a mile S.W. of Cawthorpe, disclosing the following:—

		feet.
Zone of *Ino. Brong.*	Chalky soil - - - - - - - -	2
	Broken white chalk - - - - - - -	3
	White chalk, with a layer of flint nodules at the top (no columnar band seen) - - - - - -	1
Zone of *Ino. myt.*	Marly and rubbly chalk, with *Terebratula semiglobosa* and *Rhynchonella Cuvieri* - - - - -	1
	Yellowish-grey chalk in thin beds - - - -	5

These beds are next seen near Tathwell, in a pit about three-quarters of a mile S.S.W. of the Church, as below:—

		ft.	in.
Zone of *Ino.* *Brong.*	Soil	1	0
	Broken white chalk, with flints	2	0
	Course of white chalk (junction-bed)	0	8
Zone of *Ino. myt.*	Nodular chalk, with two layers of gritty shale	1	0
	Hard greyish chalk in regular beds, with shaly partings	8	0

Beds of rather an abnormal character, but probably belonging to this zone, are exposed in a quarry by the roadside three furlongs N.E. of Tathwell; the section is as follows:—

	ft.	in.
Soil and chalk rubble	2	0
Hard yellowish-white chalk, indistinctly bedded, weathering into nodular forms, with thin seams of shale	10	0
Layer of grey shale	0	4
Grey, shaly, or laminated chalk (about 18 inches) passing down into grey calcareous shale (about 12 inches)	2	6
Hard nodular chalk	2	0
Talus	8	0
	24	10

The shaly chalk and calcareous shale are different from any bed seen elsewhere, but appear to be on the horizon of the marl band which lies at the base of the middle chalk. Here, however, there is an entire absence of the hard nodules which are usually found in that band; and it is possible the beds may belong to the upper part of the lower chalk. Compare the section near Burwell (p. 55), where a band of greenish-grey shale occurs.

There is also some doubt about the exact position of the chalk seen in the quarry south-west of Dovendale; the beds are greyish and gritty, containing *Inoceramus mytiloides*, *Terebratula semiglobosa* and *Rhynchonella Cuvieri*.

The next exposures are those in the quarries by the side of the London Road, south of Louth. One of these has been described on p. 57, the other (belonging to Mr. Clapham) is dug entirely in the Middle Chalk, and the section of this is given below:—

		feet.
Gravelly soil, with pockets of gravel and chalk rubble		2 to 5
Zone of *Ino.* *Brong.*	White chalk in thick beds, with layers of flints	30
	Similar white chalk, very hard in places (lower level)	12
	Course of hard white chalk, not much jointed	0½
Zone of *Ino. myt.*	Layer of loose grey shale	0½
	Hard gritty chalk in beds from 12 to 18 inches thick, separated by layers of grey shale with nodules	8
	Buff-coloured sandy shale, with nodules of hard chalk (*Inoceramus mytiloides*)	0½
	Hard greyish chalk, with shaly partings	4
Zone of *Bel. pl.*	Course of shaly clay, grey and purple, with many nodules of hard yellowish chalk at the base*	1½
Hard yellowish chalk, with band of pale pink		5
		64

* Mr. Rhodes obtained *Rhynchonella lineolata*, a Chelonian bone, *Ptychodus decurrens*, and other fish remains from this peculiar stratum.

The section in Paddison's Quarry to the north of Louth has already been given, p. 58, the thickness of the beds referred to the zone of *Inoceramus mytiloides* being there about 16 feet. Another good section is seen in a small quarry and lime-kiln in Elkington Pasture about 1¼ mile W.N.W. of Louth Church. As at Louth the beds here are nearly horizontal, and are as follows:—

		feet.
Zone of *Ino. Brong.*	Soil and rubble	1
	White chalk with flints	2
	White chalk, breaking into rectangular pieces	1
Zone of *Ino. myt.*	Hard-bedded chalk, with layers of shale	¼
	Hard nodular chalk, with shaly layers	5
	Grey shale, with nodules of hard chalk	0½
	Yellowish-grey chalk, breaking into small flattish lumps, with layers of shale	5
Zone of *B. plena.*	Grey and brown shaly clay, with a layer of chalk nodules at the base	1¼
Lower Chalk.	Hard-bedded cream-white chalk, with a tinge of pink in places	5
	Hard yellowish-pink chalk	3
	About	28

An old pit south of the farm called Bunkers, 2½ miles west of Louth, exposes hard nodular grey chalk in thick beds, with marly partings, which from its position is very near to the base of the chalk with flints; but the talus hides the beds which would determine its exact horizon.

At Welton-le-Wold, which is just outside the limits of Sheet 84, a small quarry two furlongs N.W. of the Church, shows 10 feet of white chalk with flints resting on the basement layer or "columnar bed," which is very well marked, and below this are 6 feet of hard yellowish chalk in thick beds, with shaly layers, the whole dipping at about 3° to the westward.

2. Zone of Inoceramus Brongniarti.

This zone first takes the ground near Welton at the south end of the Wolds and its lowermost beds are exposed in the pits already described between Welton and Claxby. Another pit about quarter of a mile north of Skendleby Lodge exhibits the following section of the chalk with flints:—

	feet.
Soil and rubble	2
Broken white chalk	3
Chalk, with flattish smooth-surfaced flints	0½
Chalk, irregularly bedded	2
Chalk, with flints of irregular nodular shapes	0¾
Hard chalk in even beds about a foot thick, with a few small flints	7
Hard chalk containing large flints at intervals	1
Chalk, hidden by talus	6
About	22

The above was measured along the N.E. face, and the beds dipped at about 3° to the S.E. The floor of the quarry is probably close to, if not on, the lower zone without flints.

Near Ulceby there are several good sections of the chalk with flints; one is in the parish pit three furlongs S.W. of the Church. This is about 20 feet deep, but the lower portion is concealed by talus. The exposed face shows hard white chalk, with two lines of large smooth flints, the intervening chalk containing a band of smaller scattered flints. The flints are all internally of a grey or purplish-grey colour, but the nodules of the middle

are of a very different shape from those above and below, being irregular, with horn-like knobs and projections. In the chalk above these arragonite structure is very conspicuous, and is especially developed along one particular line of bedding.

There is another and deeper pit about two furlongs west of Ulceby Church, showing more than 30 feet of the chalk with flints, and intersecting its plane of junction with the underlying zone. At the north-east corner of this pit the following measurements were taken:—

		feet.
Zone of *Ino. Brong.*	White chalk in rather thick beds with four band of flints and a layer of loose rubbly chalk at the base	22
	Thin-bedded chalk, with scattered flints, but partly obscured by fallen talus	8
	White chalk in thin beds, with a layer of grey flints near the base	2½
	Hard chalk, jointed vertically, and disintegrating in columnar fragments (basement bed)	0½
Hard grey chalk, weathering into shale, and thus presenting a contrast to the bed above		2
		35

The bedding is nearly horizontal, but is slightly inclined to the N.N.E., and at the bottom of the pit on the W. side about 4 feet of compact grey chalk, with layers of grey shaly marl, overlaid by columnar bed, can be examined. The same beds, with three layers of flints, are shown in a smaller pit in the fields half a mile N.E. of Ulceby Church.

By the side of the high road, three-quarters of a mile W.S.W. of Ulceby Cross, are two small chalk-pits, that on the south side of the road showing the following beds:—

	feet.
Soil and rubble	2
Chalk, with scattered flints	2
Band of grey marly clay	0½
Hard cream-white chalk in thin beds, with a few scattered flints, small and elongate	5
Layer of large nodular flints, grey inside	0¾
Very hard chalk in thick beds, with some large flints here and there	5
	15

The marly layer contains many small rolled pebbles of hard chalk, fragments of *Inoceramus* shell, *Terebratula semiglobosa*, and a small variety of *Rhynchonella Cuvieri*, which seems to be abundant. The bedding is nearly horizontal.

All the pits hitherto mentioned are in the lowermost portion of the chalk with flints; the higher beds are only found near the eastern border of the high-land by Well, Rigsby and Haugh. These beds, which contain thin layers of grey pipe-clay, are first seen in a quarry above Well Vale, and three furlongs N.W. of the Church. The section in this is as follows:—

	ft.	in.
Soil and rubbly chalk	3	0
Tabular layer of reddish flint	0	1
Broken and jointed chalk	1	6
Layer of dark grey pipe-clay	0	2
Irregularly bedded chalk, with scattered elongate flints, *Inoceramus Brongniarti*, and small *Rhynchonella*	4	6

	feet.
Thin layer of grey marly pipe-clay	0 1
Chalk in thick beds, with large nodular flints	8 0
Chalk in thinner beds, with few or no flints	10 0
	27 4

Three small faults cross these beds, the most northerly one having a throw of 4 feet, the second 2½ feet, and the third about 3 feet; the last brings in a third layer of marly clay lighter in colour than those below, and along the western face several other smaller slips are seen; the downthrow of all is on the southern side, but the exact direction of their strike could not be ascertained.

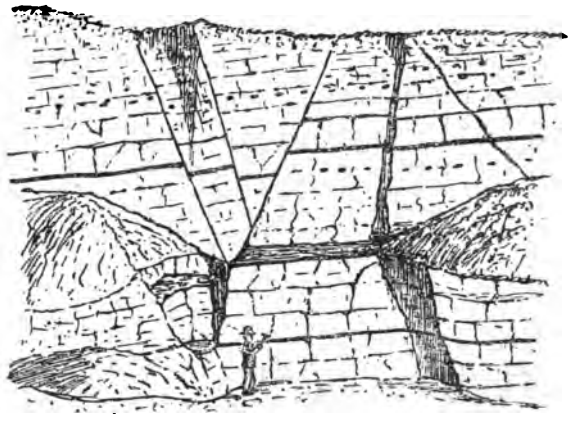
About a mile S.W. of Alford Railway Station and west of Well North Farm there is a large chalk-pit, in which the following measurements were taken about the middle of the north-western face:—

	feet.
Soil and rubble	2
Broken chalk, with a layer of flint nodules	3
White chalk, rather soft, in thick beds, with scattered elongate flints	8
Layer of dark grey pipe-clay, an inch thick	—
White chalk in massive beds, with a layer of large nodular flints	6
Harder white chalk without flints in three massive beds	5
Layer of dark clay or fuller's earth, resting on an uneven iron-stained surface	0
White chalk in three beds, with scattered flints	6
Thin continuous layer of flint, nearly black	—
White chalk, evenly bedded, with a layer of large nodular flints at the base	7
	37

The dip is about 5° to the W. or W.S.W. There are several small faults and displacements rendered conspicuous by the layers of clay and flint. The following is a sketch of two which produce a small trough fault:—

FIG. 10.

Sketch in Chalk-pit near Alford.



A smaller pit at Rigsby shows about 18 feet of the same chalk, dipping evenly to the S.W. at an angle of about 8°; the beds vary in thickness from 6 to 24 inches, and contain large smooth flints, grey inside and some of them cavernous.

At Haugh there are two quarries, one between the road and the Church, where little can be seen for the fallen talus; and another, more recently worked, about half a mile N.N.E. of the Church; here a clean face of hard white chalk is exposed, about 25 feet deep, some of the beds being very hard and massive, of a creamy-white colour. The flints occur chiefly along lines parallel to the stratification, but a few are sporadic. The dip is about 4° to the S.W. *Inoceramus Cuvieri?* was the only fossil seen.

In an old pit three furlongs S.E. of Haugh, where similar beds are shown, I found *Inoceramus Cuvieri* and *Rhynchonella Cuvieri* in flint.

Crossing the deep valley of the Calceby Beck the chalk with flints sets in again near Belleau and White Pit Houses, forming a series of broad outliers, often only separated by very narrow valleys or ravines which cut into the underlying chalk without flints. The reader will remember that the line of division engraved on the map represents the base of this chalk with flints. It is exposed in numerous quarries, but as the sections throughout the tract between the places above mentioned and the valley of the Ludd are all very similar I shall only indicate the larger and deeper quarries, where this part of the chalk may be conveniently studied.

The pit half a mile N.W. of Belleau is about 30 feet deep in chalk, with lines of grey flints, the beds dipping at about 5° or 6° to the W.S.W.

A quarry at Muckton, about 300 yards south of the Church, shows chalk beneath a thin capping of Boulder Clay as follows:—

	feet.
Dark brown clay, with stones	3
Light brown sandy clay	2
White chalk, with layers of flint	10
Thin course of rubbly chalk	—
Chalk, with large flints	1½
Course of loose rubbly chalk	0½
Chalk, with scattered flints	12
	29

There is another large quarry on the road to Cawthorpe, and about a mile S.E. of that village; this is over 40 feet deep, and exhibits the same hard white chalk with four or five layers of flint nodules and a few sporadic flints. The dip in the centre was about 6° to W.S.W., but varied in amount. *Inoceramus* sp.? was the only fossil seen.

A quarry on the main road about a mile west of Cawthorpe and half a mile south of Dexthorpe is about 27 feet deep, and shows white chalk with scattered flints and numerous *Inocerami*, underlain by white chalk in thick beds without flints.

At the place marked Saturday Pits on the map, near Kenwick Hall, there are Whiting works, and the quarry shows tough white chalk in massive beds from 2 to 3 feet thick, with lines of grey flints. The pit is in two levels, and near the top of the lower level is a layer of grey clay; the best whiting is made from the beds above this layer, those below being harder and "grittier," *i.e.*, more full of Inoceramus shell.

The lower beds of this zone with the basement columnar bed, resting on grey shaly chalk, are seen in a quarry a quarter of a mile N.E. of Raithby and they dip to the S.S.W. at about 5°.

There is another quarry five furlongs S.S.E. of Raithby, and a third about a mile to the S.E., both in chalk with flints. This division can also be examined in the upper level of the large quarry below the cemetery at Louth (Clapham's Quarry, see p. 64); likewise at the following localities near Louth:—

A pit by the roadside two furlongs west of Bunkers and nearly three miles west of Louth (25 feet deep).

A pit at South Elkington three furlongs S.E. of the Church.

A pit at corner of roads three-quarters of a mile N.W. of South Elkington, and another about the same distance due north.

A quarry near Acthorpe Farm, 1½ miles N.W. of Louth Church.*

To the northward higher beds with courses of continuous flint come in; the first good exposure of these is in a quarry about three-quarters of a mile S.W. of Fotherby. Here I found:—

	ft.	in.
Broken white chalk	4	0
Layer of grey fuller's earth	0	3
Hard white chalk, with flint nodules	6	0
Course of continuous flint, with inclusions of hard yellowish chalk	0	6
Hard creamy chalk without flints	8	6
Floor of continuous? flint.		
	19	3

Near North Ormsby there are several quarries, one, half a mile E.S.E. of the Church, is about 30 feet deep, and gives a good section of white chalk, including a layer of large lenticular flints, a seam of laminated grey marl, and a course of solid grey flint 6 inches thick with mammillated surfaces.

Another quarry due north of the Church exposes exactly the same beds, the measurements in the pits being just the same. The following are those taken in the northern one:—

	ft.	in.
Chalky soil	1	0
Thin bedded chalk, rather soft, with nodules of grey flint	4	0
Course of grey flint, very brittle, and interlaminated with chalk, thickens lenticularly up to 9 inches	0	6
Firm cream-white chalk, becoming shaly and yellowish at the base	3	0
Seam of dark grey shaly marl	0	3
Hard dull white chalk, with flat lenticular nodules of grey flint	6	0
Continuous course of flint with mammillated surfaces	0	6
Firm white chalk in thick beds, without flints	4+	
Talus	10	0

In the pit to the south the lowest bed is seen to be 7 feet thick, and contains a few small flints near the base; it rests on another course of grey flint. The lowest flint course breaks up into long flakes parallel to the stratification, a fracture which contrasts strangely with the more conchoidal fracture of the nodules. The upper flint course is in the condition of separate lenticular nodules in the first-mentioned pit, while here the flint seems to have caught up portions of chalk during the process of its formation.

Another quarry showing the same series of beds, but carrying the section still lower down, occurs in a field three-quarters of a mile N.N.W. of Ormsby, and accessible from the road to Ludborough.

The beds here visible are:—

	ft.	in.
Chalky soil and rubble	2	0
Thin-bedded firm white chalk	6	0

* From this quarry Mr. Rhodes obtained *Rhynchonella limbata, Echinoconus globulus, Infulaster excentricus* and *Hippothoa elegans* on a hinge of *Inoceramus.*

	feet	in.
Course of grey flints, partly nodular and partly interstratified with chalk	0	6 to 9
Hard cream-white chalk, with thin partings of dark grey marl near the base	3	0
Seam of dark grey laminated clay, ferruginous at the base	0	3 to 4
Hard dull white chalk, closely bedded, with flat lenticular flints at intervals	7	6
Continuous course of dark grey flint	about 0	6
Hard white chalk in thick beds, without flints	7	6
Course of irregular and lenticular flints	—	
Hard dull white chalk, as above, with small lenticles of grey flint	10	0
Hard white chalk in more massive beds	6	0
	43 feet	

There is a slight dip (about 2°) to the W.S.W., and at the west end of the quarry a small fault is seen, with a downthrow to the south of about 3 feet. The main joints run S.E. and N.W.

The highest beds found in the sheet are seen in a pit about a quarter of a mile S.W. of North Ormsby; these consist of hard whitish chalk, with courses of the peculiar flint described on p. 41; the flinty part is yellowish-brown, without any white coating or rind, and is so imperfectly or partially developed that it has the appearance of having been eaten out by acid, or replaced by the yellowish chalk with which it is intermixed, and the whole forms a single layer or floor as if it were once homogeneous. At the base there are 2 feet of cream-white chalk, with a course of solid grey flint below; bedding horizontal.

CHAPTER VII.

THE GLACIAL DEPOSITS.

Deposits of Glacial age cover a large portion of the area under description, and as they also underlie the whole of the Marsh-land there is not more than 80 or 90 square miles in the whole area which is free from a covering of Drift.

These deposits include two distinct types of Boulder Clay; the first is a clay so entirely made up of chalk débris as to merit the name of "Chalky Boulder Clay," which Mr. Searles Wood has given it; the second type comprises a series of clays, loams, sands, and gravels, more or less interstratified, the clays being always of a red, brown, or purple colour, and containing comparatively little chalk; this series includes the Purple and Hessle Clays of Mr. S. Wood.

It is also to be remarked that these two types of Boulder Clay occupy separate districts, the first being only found in the western part of the sheet, and the main mass of the second forming a plateau of low elevation which fringes the eastern side of the Wolds and curves round their southern extremity (see Map, p. 117). So different and distinct are these two masses of Boulder Clay that there is only one place in the whole sheet where the two come into contact, namely to the west of South Elkington, near Louth, and here both clays maintain their special characters to within a few yards of the line of contact, though, unfortunately, there is no open section showing the junction.

In my opinion there is good reason to conclude that the Chalky Boulder Clay is the older, and that the brown clays belong to a later stage of the Glacial Period. I propose, therefore, to describe them under the headings of Older and Newer Boulder Clays respectively.

The Boulder Clays contain a miscellaneous collection of stones and boulders, some of which are well striated, and have evidently been brought from far-distant sources: many are rocks which may have come from Yorkshire, Northumberland, or the eastern coasts of Scotland, but there are others which it is difficult to identify with any British rock and for which a Scandinavian origin has been suggested. Further, a perusal of my own notes seems to indicate that there is a certain amount of difference between the assemblage found in the lower clays and that of the uppermost (Hessle) clay, certain stones, such as quartz and quartzite pebbles, red (Triassic) sandstone, coal, and chalk débris, being at any rate more abundant in the upper than in the lower clays.*

* I regret that I did not pay more attention to this point during the survey of this district: if the observation is confirmed it would indicate that the Trias and the Chalk yielded more material to the Hessle Clay than to the lower beds.

The following is a list of the rocks of which fragments have been noticed in the East Lincolnshire Clays :—

Hessle Clay.	*Purple Clays.*
Granite.	Granites.
Greenstone.	Syenite ?
Black basalt.	Black basalt.
Diabase.	Red porphyrite.
Red porphyrites.	Gneiss.
Gneiss.	Red quartzite.
Red, white, and yellow quartzites.	Red micaceous sandstone.
Quartz pebbles.	Purple conglomerate (? O.R.S.).
Carboniferous limestone.	Carboniferous limestone.
„ sandstone.	„ ironstone.
Coal (abundant).	Coal.
Shelly limestone (Jurassic).	Shelly limestone (Jurassic).
Hard shale (Kimeridge Clay).	Soft red sandstone (Trias).
Soft red sandstone (Trias).	Chalk pebbles.
Spilsby sandstone.	Flints.
Chalk pebbles (abundant).	
Flints.	

Mr. J. J. H. Teall, to whom some of these stones were submitted, has kindly furnished me with the following notes on two specimens which he had cut for microscopical examination :—

"A.*—Médium grained crystalline granular rock composed essentially of plagioclase, augite, magnetite or ilmenite, and a few serpentinous pseudomorphs after olivine. The plagioclase gives lath-shaped sections and the augite occurs in large irregular plates.

"The rock furnishes a beautiful illustration of the 'ophitic texture.'

"It closely resembles the Kinnehulle diabase described by Törnebohm† ; but too much stress must not be laid on this, as the rock-type is not an uncommon one. Nevertheless, it is just worth noticing that this rock resembles certain Scandinavian rocks more closely than it does any British rock that I am acquainted with.

"B.‡—Rock composed of porphyritic crystals of plagioclase, augite, and olivine (?), in a compact black ground-mass. Under the microscope the ground-mass is resolved into felspar microlites and granules of augite and magnetite.

* A is from a boulder known in Louth as the "Bluestone," and preserved in the yard of a house which was formerly an inn, with the sign of "The Bluestone."

† Neues Jahrbuch, 1877, p. 265.

‡ B is from a boulder taken out of the Hessle Clay by the road near Hallington.

"This rock is allied to some of the Scotch Carboniferous Basalts. It is, however, remarkable for its freshness.

"I can say nothing about its probable source."

§1. The Older Boulder Clay.

The main mass of this clay was surveyed by my colleague Mr. A. Strahan, who supplies the following account of it.

The Boulder Clay of the western margin of the map is portion of a great sheet which extends almost continuously down the slope of Kimeridge to the west, to the edge of the fen by the River Witham. This portion of the sheet consists of a mass of ground-up chalk with scratched flints and boulders of harder chalk scattered through it, and so completely envelopes the ground west of the Steeping Valley, as, at first sight, to convey the impression that it is solid chalk. The actual nature of the underlying rock, however, is occasionally shown in the deeper valleys, as in that north-west of Greetham, and in the tributary of the Bain, which rises near Belchford. On the east this sheet is abruptly terminated along the top of the hills which form the western side of the Steeping Valley; the manner of its termination and the occurrence of small outliers in the higher hills in this valley strongly suggesting that it must have been formerly continuous up to the edge of the chalk escarpment.

Description of Sections.

Near its eastern margin this mass of Boulder Clay occasionally becomes gravelly. Near the Greetham and Fulletby Road, about half a mile and one mile north of the former place respectively, are two gravel pits. The first is partly in chalky Boulder Clay and partly in yellow gravel, with large flints, apparently unstratified, but containing a few veins of sand, and partly overlaid by a loamy bed. The second pit shows:—

	ft.	in.
Chalky loam eaten into pipes and hollows by the overlying soil and rainwash - - - - -	1	3
Coarse flint gravel in a chalky matrix - - -	4	0
Finer flint gravel in a chalky matrix with a few lenticular bands of chalky loam - - - - -	12+	

The materials in this pit are rudely sorted as above into nearly horizontal bands. The flints in the coarse gravel average 8″ × 6″ × 4″, in the finer 4″ × 3″ × 2″. They are well scratched and bruised all over. The bands of chalky loam are 4 to 6 inches thick and 4 to 8 feet long.

Similar gravelly patches occur on Fulletby Hill. They are possibly the result of long weathering on thin outliers of the chalky Boulder Clay, patches of which of the usual character are found in them. The deposit occurs a little to the east of the highest portion of the hill, as though with a tendency to run down a slope in this direction. It is worked for road metal.

The gravel-pit on the chalk outlier, one mile north of Belchford, is excavated in a loose deposit of flints and rounded pebbles of chalk. The sides have run in, and it is difficult to say whether it is stratified. It appears, however, to be of a gravelly rather than of a Boulder Clay type. The patch is extremely small.

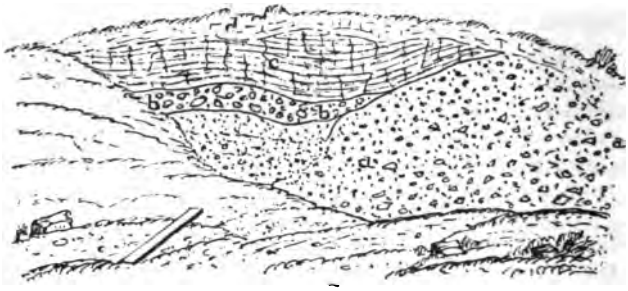
The gravels above described must not be confused with the series of sands and well-washed and stratified gravels which underlie the chalky Boulder Clay elsewhere (as at South Willingham, in Sheet 83). They are rather gravelly patches or pockets in the Boulder Clay. The stratification described in one of the pits near Greetham is such as frequently may be seen in Boulder Clays. It is not possible to draw a hard and fast boundary to these gravels; the line on the map may be considered as an approximate boundary to this gravelly type of Boulder Clay.

A. STRAHAN.

Small patches of similar gravel occur in connexion with the spurs and outliers of Boulder Clay to the south-east of the above. One of these is near Northfield Farm, six furlongs N.N.W. of Mavis Enderby Church. The section visible here in 1877 is shown in Fig. 11.

FIG. 11.

Section in Gravel-pit near Northfield Farm.



	feet.
d Brown sandy soil	1
c Hard yellowish sandy loam	2–3
b Layer of flints and lumps of clay	1
a Chalky gravel, fine and sandy at the top, coarser below, both stratified	8

The loam thinned out southward as represented, and the underlying gravel changed gradually into coarser and coarser material, until there was little trace of bedding left. The stones composing it were: hard white chalk, red chalk, flints, Neocomian sandstone, basalt, and a few quartz pebbles; the sand consisted almost entirely of small grains of chalk; greatest depth exposed about 14 feet. This patch of gravel is entirely surrounded by chalky Boulder Clay of the usual type, except on the northern side, where it overlies the Spilsby Sandstone.

The outlier of Tealby Clay east of Hagworthingham is capped by a smaller outlier of gravel which was formerly dug for road material; this seems to have been exhausted, but appears to have consisted chiefly of large flints enclosed in a matrix of sand and pebbles.

A very small patch of similar gravel forms a hillock about half a mile S.S.E. of Hagworthingham Church. A pit opened in this showed the following section:—

	feet.
Fine flint gravel in irregular beds, some coarse, some fine, with sandy matrix	15
Stiff dark clay with large stones	5

From the bottom bed a large angular mass of compact black basalt had been turned out, measuring $3 \times 2\frac{1}{2} + 1\frac{1}{2}$ feet, and looking like a fragment of a polygonal column.

The high ground south of Raithby is capped by an outlier of white chalky Boulder Clay, which has been dug in several places for spreading on the light sandy lands. It is known locally as white marl, and is entirely composed of reconstructed chalk; the only stones seen in it were flints and small fragments of chalk.

Marden Hill, near East Keal, (see Fig.13, p. 83,) also has a capping of the same Boulder Clay, which passes into gravelly loam, and has been dug for gravel, but no good section was open at the time of my visit.

Another small outlier of the Boulder Clay occurs on the Spilsby Sandstone, half a mile N.W. of West Keal. South-west of this, and at a much lower level (north of the farm called Laythorpe), is another small patch of chalky clay, occupying about half an acre. A pit had been dug in it for a depth of 7–8 feet, and boulders of chalk, flint, septaria and Neocomian ragstone were thrown out. Two other larger patches (partially covered by gravel) link this on to the main mass near Revesby.

On Kirkby Hill, about a mile east of Miningsby, there is a pit whence the "white marl" has been dug for burning into lime; about 10 feet of intensely chalky Boulder Clay is here exposed, of a yellowish or creamy-white colour, and crammed full of lumps of hard chalk and pale grey flints, evidently brought from the Middle Chalk to the northward.

Chalky Boulder resting on clean blue Kimeridge Clay was seen in a deep ditch by the roadside about half a mile S.E. of Miningsby. The base is again seen in a ditch at the south-east corner of Revesby Park; here the chalky clay passes down into a dark blue clay with chalk stones, and when the Boulder Clay again emerges on the south side of the Revesby Gravel it is all of this dark blue type; consequently, as the land is nearly level, the boundary between it and the Kimeridge Clay is very uncertain. Greyish-blue Boulder Clay was seen beneath sand at the bridge over the Catch-water south of Shire Wood, and half a mile south of this it comes to the surface.

At the farm a mile and a half S.S.W. of Revesby I was told that the well was sunk 15 feet through clay with chalk stones into sand with a good supply of water. A dark peaty soil covers the surface, and occasionally there are pipes and pockets of sand and gravel in the clay. At Revesby Bank the subsoil appears to be clean blue Kimeridge Clay, so that the Boulder Clay thins out between this and West Lane.

The Chalky Boulder Clay probably swept eastward up to and out the Chalk Wolds, but only one small outlier remains to show its former extension in this direction, namely at Maidenwell, about five miles south of Louth. The Boulder Clay here mapped lies partly on the top of a hill and partly on its northern flank, descending to a much lower level near the farmstead, as if it originally filled a valley or hollow in the surface of the Chalk. Like the main mass to the south-westward it is a white marly clay with occasional flints, and it passes at both ends beneath beds of sand and gravel which appear to be of newer date.

The Boulder Clay near North Elkington is the termination of a long sheet or tongue of chalky clay, which gradually climbs to the top of the chalk escarpment in Sheet 83 and spreads eastward into Sheet 84. A pit three furlongs north of the farm called Boswell showed about 10 feet of grey clay, full of flints and stones, resting on white marly clay, full of bits of chalk at the bottom. In the grey clay I found a block of granite, one of white quartzite, a piece of coal, and several small quartz pebbles. The occupier of the farm informed me that the grey clay is everywhere underlaid by the white chalky marl, and that the solid chalk was found about 20 feet down in the well at Boswell House. Near the entrance to the drive there is a pit in reconstructed chalk which forms part of the white marl. Here it consists entirely of lumps of chalk with a few flints embedded in a marly paste, the whole being very hard and compact.

§ 2. The Newer Boulder Clays.

General Description.

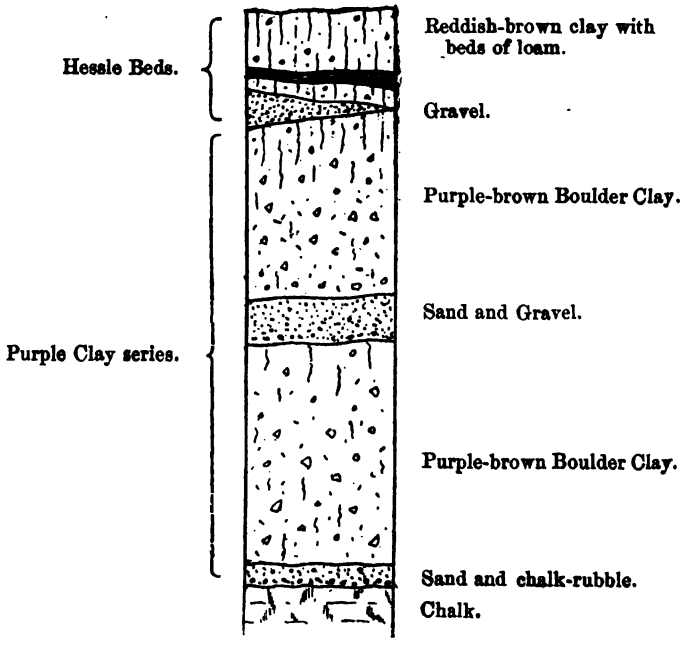
I have elsewhere given my reasons for regarding the Brown Boulder Clays which flank the eastern side of the Lincolnshire Wolds as of later date than the Chalky Boulder Clay just described.* I have also stated my belief that these brown clays form a continuous succession of beds, and that though they contain layers of gravel and sand at several horizons, none of these can be taken as coinciding with a plane of denudation and unconformity. I hold it therefore quite illogical to call the upper part of this series Post-glacial and the lower part Glacial, as Mr. S. V. Wood maintains.

The conclusions I have come to are the result of six years' work in Lincolnshire and of the mature consideration of all the observations made during that time. The beds vary so much, especially in the southern part of Sheet 84, that no diagrammatic representation would hold good for many miles; but in the eastern and northern parts of the map something like the following succession can be made out in many localities.

Fig. 12.

General Succession of Newer Glacial Deposits.

Scale, 20 feet to an inch.



* Quart. Journ. Geol. Soc., vol. xli., p. 114.

With regard to the conditions under which these Boulder Clays were formed, it is of course a disputed point whether the agency involved was that of land-ice or sea-ice; and it would be out of place to enter into any discussion of this question in the present Memoir. I shall therefore content myself with expressing an opinion on the intimate relations of the two Boulder Clays of East Lincolnshire and with stating the reasons for my belief in their marine or littoral origin.

In the first place, then, I regard the Hessle and the Purple Clays as similar in essential characters and in their mode of occurrence, and believe that both of them must have been formed in the same way and by the same agency, whatever that was.

Mr. Searles Wood has made a great distinction between the two clays, speaking of the Hessle Clay as being specially a "valley deposit" and a "valley-formed clay;" but the Purple Clay is just as much entitled to be called a valley deposit as the Hessle Clay, since both occur together in the valleys near Louth. They appear to be merely members of one continuous group or series of Glacial deposits. On this point I believe all those who have recently examined these deposits in Lincolnshire and Holderness are agreed, namely, Professor James Geikie, Mr. W. G. Lamplugh, Mr. C. Reid, and myself; although we are not in agreement with respect to the conditions under which they were formed.

It has indeed been suggested that the Hessle Clay is merely an alteration product, and has resulted from the weathering of the surface portions of the Purple Clay; the reddish colour being imparted by the oxidation of the iron, and the grey streaks being developed by the action of the carbonic and humic acids on some ingredients of the clay during the passage of water containing such acids through the cracks which traverse the mass. I think it highly probable that the colours of the Hessle Clay have been produced by such a process of oxidation and weathering, so that the Hessle Clay may originally have borne a greater resemblance to the Purple Clay than it does now*; but there remain important differences between the two clays, even when those of colour are eliminated, and there are several facts which militate against the view above suggested.

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* To test this, samples were sent to Mr. Grant-Wilson for analysis with the following results:—

The sample of Purple clay contained—	
Protoxide of iron - -	4·06 p.c.
Peroxide of iron - -	·65
The sample of Hessle clay contained—	
Protoxide of iron - -	2·34
Peroxide of iron - -	3·55 p.c.

In the first place I observed several localities near Louth where clay of the "Purple" type, that is clay of a dark purple-brown tint, stiff and homogeneous, with very few fragments of chalk, occurred at the surface and had not therefore suffered alteration, although exposed to the same surface agencies as the surrounding clay of "Hessle" type.

Again, if we are to regard the Hessle Clay as in every respect an altered form of the Purple, owing its characters to the chemical action of percolating water, we should certainly expect it to contain a smaller proportion of chalk pebbles than the underlying clay; this, however, is not the case: the number of chalk pebbles and pellets is much greater in the Hessle than in the Purple Clay. They are certainly very small, and it is not improbable that they have been diminished in bulk by solution, but if so, then the original difference between the clays in this respect must have been even greater than it is now, for in some parts of the Purple Clay pebbles of chalk are few and small pellets still rarer.

There are other differences between the two clays, especially as regards their texture. The Hessle Clay has a large admixture of sandy-matter, and has consequently a gritty feel, while the Purple Clay is purer and more plastic.

I regard them therefore as essentially distinct.

With respect to the origin of these Boulder Clays my own opinion is that they have been accumulated by the agency of coast-ice, a view which has grown stronger as my experience of them has increased, and the following are some of the considerations (suggested by the survey of Sheet 84) which have led me to this conclusion:—

1. The whole series rest on a plain or platform of marine erosion which passes eastward beneath the bed of the North Sea (see the Plate of Sections).
2. The western border of this platform appears to be a line of buried cliffs, against which both the Purple and Hessle Clays are banked.
3. Thick beds of sand and gravel are found in both these clays, just in front of the old shore-line, all along the eastern side of the Wolds; one of these gravel beds contains marine shells in some abundance (see p. 91) No one could doubt that this was a beach-gravel, and yet it is intercalated between sheets of Boulder Clay.
4. Some of the valleys which intersect the Wolds are occupied and partially filled with prolongations of these glacial beds, and in two of these, namely, the Calceby Valley and the Welton Valley, near Louth, the materials are chiefly stratified gravel and sand, which have clearly been accumulated by the action of currents.
5. The sand banks at the mouth of the Skendleby Valley and those at the foot of the Neocomian hills south of Spilsby

are just the deposits we should expect to find in such a position if they were formed along a shore-line.

6. Both clays, but especially the Hessle Clay, frequently include layers of laminated loam and silt, which are evidence of the frequent interposition of a stratifying aqueous agency.
7. The present surface of the Boulder-Clay land is not a sculptured surface, but rises into irregular ridges, mounds, and hummocks, which have no relation to the drainage of the district; in many places they have blocked the natural drainage and enclose hollows which were formerly bogs and meres. The irregularities of the surface are therefore probably due to original deposition, and yet some of the mounds are 40 or 45 feet above the bottoms of the neighbouring hollows.

Whatever bearing the last consideration may be deemed to have upon the question in dispute, it is at least an interesting and noteworthy fact. The general surface of the Boulder-Clay land on the east side of the Wolds is so little higher than that of the Marsh, and the whole district is so little above the sea-level that the erosive action of rain and rivers is reduced to a minimum; it is clear that in many places the irregularities of the surface existed before the present streams came into being, and that the position of the mounds and ridges guided the course of the streams. It is probable in fact that the general form of this surface has hardly been modified by any agencies since the accumulation of the materials which compose it.

By reference to the map (Sheet 84), the reader will perceive that the tract of Boulder-Clay land, which lies between the Wold and the Marsh, ranges in a direction exactly parallel to that of the Wold Hills, namely, from N.W. to S.E.; and that this tract preserves an average width of between four and five miles as far south as the vicinage of Alford. South-east of Alford it is broken up into a number of more or less isolated mounds and ridges, which rise like islands from the level of the Marsh-land, and which must really have been islands at the time when the clays and silts of the Marsh were being deposited.

There can be little doubt that the Boulder-Clay tract originally extended much further to the south-east, completely across the Wash in fact, to the north coast of Norfolk, where Brown Boulder Clay of precisely the same character has been found to occur. This plateau was gradually eroded and worn back by the waves of the North Sea in Post-glacial times just as the Holderness coast has been wasted continuously down to the present day.

South of Chapel and Hogsthorpe this Post-glacial erosion cut deep into the Boulder Clay land, and reached westward, near Orby, to within a mile and a half of the Chalk hills, while all round the southern termination of the Wolds the plateau of Boulder Clay is reduced to a comparatively narrow strip of land,

which terminates very curiously in the promontory of Stickford and Stickney.

Description of Sections.

In describing the local details and exposures of these beds it will be convenient to take Firsby Station as a starting point, both because it would probably be an actual starting point for anyone intending to examine them, and because from Firsby there are three lines of departure, according as the Glacial deposits are followed westward along the northern border of the Fenland, north-westwards towards Partney and Skendleby, or northward along the course of the railway and round the end of the Wolds.

Moreover, as it is impossible to dissociate the sands and gravels from the Boulder Clays or to say with which portion of the Boulder they are most closely connected, all the exposures seen in one locality will be described together, whether of sand, gravel, or clay.

Commencing then at Firsby Station the observer will naturally first examine the Boulder Clay exposed in the railway cuttings, which is of the usual type presented by the uppermost layer of clay; in colour it is reddish-brown, mottled, and streaked with ash-grey, tolerably stiff when first cut, but crumbling into small cuboidal fragments under the influence of rain and frost; it is full of very small bits of chalk, mostly about the size of peas, and the greater number of these consist of pure white chalk, brittle and rather soft, resembling the uppermost soft chalk of Yorkshire. There are also larger pebbles and fragments of hard grey chalk, like that found at the south end of the Lincolnshire Wolds, a few miles northward, together with flints and fragments of the following rocks:—Gneiss, Basalt, a reddish Felstone, Septaria (from the Kimeridge Clay), Sandstones, and Quartz pebbles. Mr. Skertchly* also mentions Lincolnshire Limestone, Keuper Sandstone, Coal-measure Sandstone, Silurian Limestone, and a very hard red jaspery Gritstone. Many of these stones are striated, and I found one piece of hard chalk which was bored by a burrowing sponge like those to be hereafter mentioned in the Aby gravel. Mr. Skertchly states that he found a single rolled specimen of *Trophon clathratus* in the clay. Though generally stiff and unstratified it passes up near the signal-box into a loose brown loam with very few stones, and examination of the stiffer portions in hand specimens shows that the clay is crowded with particles of coarse sand, giving it a gritty feel.

About three furlongs south of the station, near the new bridge over the line to Wainfleet, a fresh excavation was made in 1881, exposing about 6 feet of this red-brown Boulder Clay, overlain apparently at the south end by several feet of sandy loam. A boring was made near the bridge for water, passing through the following beds, according to information given me by Mr. Wield of the company's engineering department:—

	feet.
Marly clay (as seen in excavation)	9
Sand and gravel	2
Soft Clay, with a few stones	7
Sand and gravel, with water at bottom	6

It is evident therefore that there are two beds of sand and gravel interstratified with the Boulder Clay hereabouts, so that the gravelly beds seen at the surface sometimes overlie Boulder Clay, and sometimes rise from beneath it, according as the irregularities of deposition and the inequalities of the ground lead to the exposal of one or the other.

Gravel has been obtained from one of these beds in a pit half a mile S.E. of the station, but is now partly filled up; in 1877 it showed gravel and sand in irregular and seemingly contorted masses, overlaid in the hollows of its surface by brown Boulder Clay and loam. In 1881 an exposed face showed 6 feet of sandy loam with stones, below which gravel had been worked. The pebbles thrown out were chiefly Chalk and Flint, but I also saw Quartz, Granite, a Red Sandstone, and lumps of the paper-shales from the Kimeridge Clay.

* Geology of the Fenland (Mem. Geol. Survey) p. 209.

At the railway station the thickness of the upper Boulder Clay is 10 feet, and from the gravel below an unfailing supply of water is obtained.

At Great Steeping gravel has been dug from below Boulder Clay; pits opened in 1877, in a field two furlongs N. of the point where the road crosses the stream, showed the following beds:—

	feet.
Soil and reddish silt	4½
Stiff brown Boulder Clay	3½
Good flint gravel	2
White sand, with water	7+
	17+

The workmen stated that southward the silt thinned out or passed into clay, and that there was always 3 or 4 feet of stiff stony clay above the gravel; at the top of the latter they had found a few hazel-nuts.

The larger pit to the south of above was not being worked at the time of my visit, but in one corner about 8 feet of Boulder Clay was visible; here, as elsewhere in the neighbourhood, its colour is a reddish-brown, mottled, with patches and streaks of bluish-grey.

The owner (Mr. Hardy) stated that its thickness is about 10 feet, that of the sand and gravel below being also 9 or 10 feet. Boulder Clay is seen in the shallow cutting on the railway west of Great Steeping Church, and is overlapped by the alluvial warp of the stream. At the cottage on the North side of the line its thickness in the well is said to be 20 feet, but at Steeping Mill the gravel is nearer the surface, being reached through 2 feet of warp and 7 or 8 feet of clay.

The land on the other side of the river consists of soft red loam and sand, seen in the ditches to a depth of 3 feet; most of Halton Fenside stands on this deposit, which appears to pass westward into or under Boulder Clay; both Clay and loam are underlaid by gravel, from which water is everywhere obtained at a depth of from 10 to 14 feet. At Hubbard Hill there is silt between the clay and gravel, the following being the section here according to Mr. Skertchly*:—

	feet.
Clay	6 to 7
Marly silt	3 ,, 4
Sand and stones	10 ,, 12
About	20

Along the Catch-water, Boulder Clay may be seen wherever ditches run into it, but northward the soil becomes more loamy again, and in the lower ground N.E. of Toynton St. Peter's sand and loam are found. From this village the Boulder Clay extends westward through Toynton Fenside to Keal Coates, keeping much at the same level, and forming a kind of terrace between the Fens on the south and the hill slopes to the north.

Wherever wells are sunk through it gravel and sand with water are found below; the thickness of the clay varies much, and in some places thins greatly, allowing the subjacent sands and gravel to approach the surface.

The northern edge of this terrace, skirting the foot of the high ground which stretches from Halton Holgate to West Keal, presents a singular and interesting feature. These hills consist mainly of the Spilsby Sandstone, based upon Kimeridge Clay, the junction line of the two formations occurring about two-thirds of the way up the outer slopes. The remarkable point is that a series of sandy banks and hummocks are developed all along the edge of the Boulder Clay; these follow all the sinuosities in the outline of the ground, and are banked up against the Kimeridge Clay, so that the latter only appears as a narrow band between the Neocomian sands above and the banks of sand below.

The windmill north of Halton Holgate Station stands on the first of these sand banks, but its extent is somewhat uncertain, and great diffi-

* Geology of the Fenland (Mem. Geol. Survey) p. 289.

culty was experienced in mapping this particular locality, for subaerial detrition had produced such a depth of sandy and loamy soil that the junctions of the several formations are quite obscured; water was obtained by sinking through the sand bank, and springs are thrown out along its southern edge, where it appeared to abut against the Boulder Clay, this clay, having its ordinary characters and full of small chalk pebbles, being seen in the railway cutting just below. In sinking a well at the station they passed through brown Boulder Clay into Blue Clay without obtaining a supply of water, so that the Hessle Clay is not here underlaid by sand, but probably thins out against the slope of the sand bank on the north.

West of this point and near the centre of the bay-like recess which exists between the two Neocomian promontories of Halton Holgate and Toynton All Saints, there is another elongated mound of reddish loamy sand; and east of the latter village a similar but higher mound is banked up upon the Kimeridge Clay to a greater height than the base-line of the Spilsby Sandstone, of which at first sight it seemed to form a part. Southward and eastward, however, it passes into or is overlapped by Hessle Boulder Clay.

All these sand mounds were probably once connected, but the rivulets proceeding from the numerous springs have cut channels for themselves and have broken up the continuity of this part of the bank. From Toynton westward, however, it is still continuous, and forms a kind of irregular terrace between the scarp of the sandstone above and the still lower plain of Boulder Clay on the south.

In a ditch commencing about a quarter of a mile S.W. of Toynton Church the following succession was noted in walking from N. to S.:—(1) Blue (Kimeridge) clay, (2) reddish Boulder Clay with chalk stones, (3) reddish loam and sand; beyond this there was a sandy soil or wash with Boulder Clay on the lower slopes, which again passed into a sandy loam where the watercourse crosses the road to the south.

A tongue of loamy sand runs up into the hollow or gulley east of Keal Church, and its outlet is almost blocked by a high bank or mound of this sandy drift. The whole collocation of beds here points to the conclusion that the older formations formed a shore-line against which the later Glacial beds were accumulated; indeed, the outline of this shore seems to have undergone very little change since the end of the Glacial Period; the streams have only succeeded in cutting their channels a little deeper and in eating their way through the banks of sand and clay left by the retreating ice.

The terrace above mentioned is continued below East Keal and widens out towards West Keal, most of which village is situated upon it. In the ponds on the south side of the road through West Keal a sandy and stony clay is exposed, containing many boulders of Neocomian ragstone derived from the hills above; in the pond by the lane-side, half a mile south of West Keal Hall, a stiff red loamy clay is found, and this passes southwards into stiff reddish mottled clay with a few chalk pebbles. The wells in the village find a weak supply of water at a depth of 14 feet in a loose kind of sandy and stony clay. The position of this sand bank is indicated on the section, Fig. 13, p. 83.

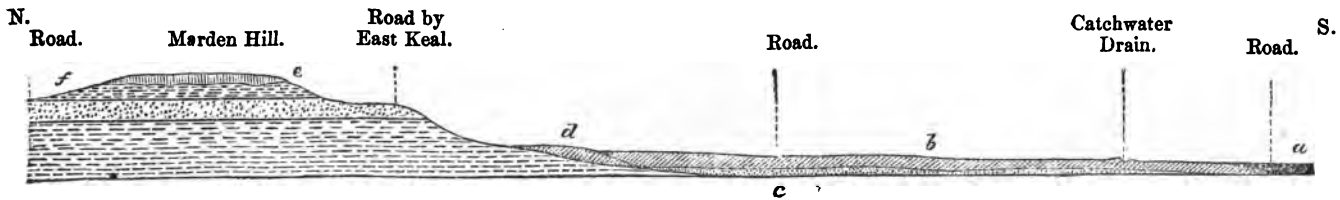
This bank-like edge of the Hessle Clay makes a still more conspicuous feature here, for it begins to draw away from the foot of the hills, leaving a slight hollow or depression, in which the subsoil is really Kimeridge Clay, but obscured by a sandy wash of some thickness. A little further westward the sandy portion of the bank appears to terminate altogether, being nearly coequal in its extension with that of the Neocomian sandstone above, from which its materials have evidently been derived.

The bank-like feature is, however, continued southwards, and the deposit forms an irregular undulating ridge extending to and beyond Stickford. On the road from West Keal to Hagnaby a reddish stony clay is found, and this passes southwards into regular Boulder Clay with occasional patches of stony loam. At the farm one mile S.E. of Hagnaby Church (near the site of the old windmill) the well has been dug to a depth of 21 feet, through "a sticky clay with bits of chalk with a seam of gravelly sand at the bottom," from which water was obtained.

FIG. 13.

Section from Marden Hill to East Fen.

Scale 3 inches to a mile.

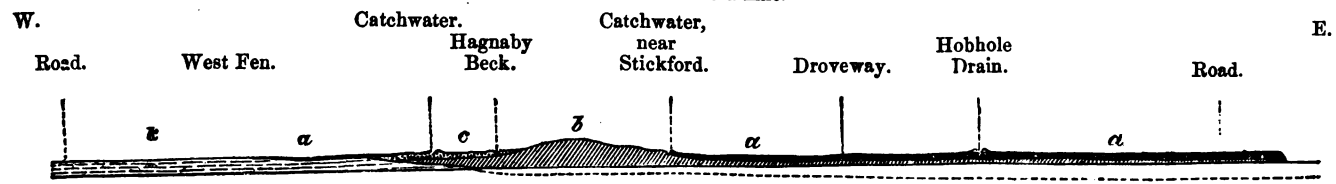


a Fen beds.
b Brown Boulder Clay.
c Sand and gravel.
d Sandbank.
e Chalky Boulder Clay.
f Tealby Clay
g Spilsby Sandstone.
k Kimeridge Clay.

FIG. 14.

Section from New Bolingbroke to East Fen.

Scale one inch to a mile.



a Fen beds.
b Brown Boulder Clay.
c Sand and gravel.
k Kimeridge Clay.

Westward the country slopes gently towards Hagnaby Beck, the course of which lies through a series of sands and gravels that appear to be of more recent age than the Boulder Clay. The position of the Boulder Clay and its probable relations to these sands and the underlying Kimeridge Clay are shown in Fig. 13, p. 83, which, with Fig. 14, were originally drawn for my paper published in the Quart. Journ. Geol. Soc., vol. 35, p. 397, 1879. They are inserted here by permission of the Council.

The brown (? Hessle) Boulder Clay does, in fact, come to the surface again on the other side of the Hagnaby Beck, and was seen in the ditches along the road from Hagnaby Corner to Kirkby Bridge, where it is again cut out by gravel.

About Stickford the Hessle Clay is a brown sticky clay, slightly mottled, and containing chalk fragments, but these of very small size; it is exposed in the deep-cut drain by the chapel on the road leading to the Fen-side. In the N.E. part of the village the clay is from 14 to 18 feet thick, and is underlaid by a bed of sand and gravel which yields a water supply for the wells; but this seems to thin out westward, for at the Red Lion Inn near the Church only a weak spring of water in a bed of dark sand was reached at a depth of 30 feet, and the well was sunk for another 30 feet through "brown clay with little white stones," similar to that found above. The Boulder Clay here, therefore, would appear to be more than 60 feet thick.

At Bargreen Bridge the same clay is found, but its colour here is a more uniform dull purplish-brown; it is full of very small chalk pebbles, and it crumbles into small cuboidal lumps when struck with a spud or pick. The ridge here is reduced to a very narrow neck, but it widens out again towards Stickney and forms an elevated ridge, separating the two fenny districts known respectively as West Fen and East Fen. This prolongation is outside the limits of Sheet 84, but is shown in the Sketch Map on p. 117; south of Stickney there is a gap in the ridge filled by Fen deposits, but the Boulder Clay sets in again at Sibsey Norland and continues through Sibsey itself, forming a long low island surrounded on every side by the flat sea-like plain of the Fens. Southward and eastward it is known to underlie the Fen deposits (see well at Leake, Appendix, p. 160).

Returning to Firsby and walking northward up the line, clean reddish loam is seen opposite the gashouse, overlaid by stiff Boulder Clay, which is succeeded further on by a red laminated sandy loam. West of the railway, and just one mile N.N.E. of Firsby Station, is a pit where the following succession was seen (1877), the lower beds being hidden by water:—

	ft.
Dark brown clay with stones	3
Reddish loam, without stones	4
Purple-brown clay, with stones	1
Sand and gravel below	—
	8 ft. seen.

The pit is opened on rising ground, and the Boulder Clay appears to arch and dome over the gravel below as if the latter was thicker than usual, and formed a bank or hummock. The owner (Mr. Hardy, of Steeping) informed me that the working was about 20 feet deep, the thickness of the clays being from 9 to 10 feet; he also said there was more gravel here and less sand than in his other pits at Great Steeping.

Westward the clay thickens: at Monksthorpe it is 14 feet, and to the north in Monksthorpe Field 17 or 18 feet. At the same time the underlying beds of sand and gravel appear to thin out, for they are not found beneath the Boulder Clay at Ashby, where the river has cut down to the Kimeridge Clay below. There is, however, a curious mound of sand and loam north of Ashby Church, which recals the aspect of those near Toynton.

At the Manor-house, N.W. of the Church, the Boulder Clay presents very abnormal characters, being a stiff bluish clay, mottled with buff colour, and in the marshy ground north of the house the ditches show similar bluish and yellow clays which contain a few stones, though not many, and appear to be glacial.

Crossing the Skendleby Beck Boulder Clay, of the reddish type, can be traced along the road to within a quarter of a mile of Partney Church. Here it ends abruptly, and the Spilsby Sandstone emerges from beneath it, and I never found the smallest shred or patch of Glacial Clay to the westward of this point, nor have I any reason to suppose that it ever extended further up the valley of the Steeping Brook (see Chapter IX).

Northward, however, the glacial beds extend for some distance up the valley of the Skendleby Beck; and here again the Boulder Clay is associated with large mounds and banks of sand and gravel which look like shore deposits.

The farm of Skendleby Holmes stands upon a bank of yellowish Boulder Clay, the western border of which has been trenched upon by the little beck coming down from Dalby. It may have been flanked by a sand-bank which this erosion has destroyed. To the N.E. there is gravel in the low ground with a mass of Boulder Clay on the slope above, and at a still higher level gravel again forming a bordering bank or terrace which curves round the promontory of Chalk and Neocomian at Skendleby Thorpe. In a deep ditch through this bank, two furlongs south of this farm, 2 feet of soft yellow sand is seen, underlain by 4 feet of hard compacted chalky gravel, which passes down into a kind of Boulder Clay which contains more stones than clay.

A tongue of Boulder Clay has even been pushed well into the narrow valley to the north-west of Skendleby, and was seen in a newly-cut ditch (1879) at the bottom of this valley half-a-mile N. of Skendleby Thorpe, underlying 2 or 3 feet of brown sandy loam or rain-wash. It is here a tough brown clay, mottled with grey, and full of small bits of chalk; the edge of it is also seen in the pathway leading down into the hollow excavated by the spring on the east side of the valley.

By the farm buildings, 300 yards north of the Church, a ditch section shows dark brown Boulder Clay, full of chalk fragments, banked up to the base of the Red Chalk, which crops out at the corner of the stables. This bank of Boulder Clay stretches continuously southward, and the southern opening of the valley is blocked with great mounds of sandy loam and Boulder Clay lying on the north side of the road to Partney. There are patches also of hard chalky gravel in the hollow interspaces, but so mixed up with Boulder Clay that they cannot all be mapped. The bank, intersected by the road to Partney, appears to consist of gravel overlaid by a stiff sandy loam. The form of the ground here strikes one as being not a sculptured surface, but one of formation, the tumultuous mounds of clay and gravel remaining just as they were originally heaped up by the ice; if one could suppose a glacier descending the Skendleby Valley, they would be regarded as its moraine, but we are not obliged to resort to that supposition in order to account for their existence. The strip of alluvium in the valley above has clearly been formed in consequence of this block below.

A similar tongue of Boulder Clay is thrust up the valley between Scremby and Candlesby; a well, two furlongs S.E. of Scremby Church, was bored through 32 feet of brown clay, full of stones into gravel, so that the depth here is considerable. The western side of the Candlesby spur is flanked by a narrow bank of gravel.

At Candlesby the Boulder Clay rises to the top of the Neocomian ridge, having been pushed apparently up the slope from the eastward. The ridge of Neocomian Clay is evidently continued underneath it eastward to Gunby, where it comes to the surface again and forms a small inlier surrounded by glacial clay of a reddish-brown colour and very loamy in places. At the farm, N.E. of the Church, the depth of this clay in a well is said to be 25 feet, but in the churchyard I was told that the brown

clay with stones was only 6 feet deep and was underlain by reddish sand and "ironstone." Southward, however, the Boulder Clay thickens rapidly, and seems to be 40 feet deep near the Oak Holt (see Appendix, p. 157).

Returning once more to Firsby we may note the sections observed on the eastern side of the railway. An inspection of the Survey Map will show that the continuity of the plain of Boulder Clay is broken by several patches of gravel: these are probably connected with the bed of gravel which is here intercalated between two sheets of Boulder Clay, which appears to be heaped up into a series of mounds or ridges from Irby through Bratoft to Burgh Field, near the railway station. Gravel has been dug at all three localities, but no pits were open at the time of my survey.

Near Bratoft the thickness of the upper clay varies very much, as testified by the depth at which the underlying gravel is struck in sinking wells; thus at the east end of the village it is 30 feet thick; where the stream crosses the road to Burgh it is only 10 feet, which thickness it maintains for some distance to the eastward, according to my informants; but at the Burgh gravel pits to the north of this road and about a mile west of Burgh Church the gravel is only from 3 to 6 feet below the surface, but thickens again to 8 feet at the farm three furlongs west of Ivy House. The gravel pit above mentioned is one of the most interesting sections in Lincolnshire, on account of the Mammalian remains which have been found it it. The succession here visible, at the time of my visit in 1877, were as given below:—

	feet.
Purplish-brown Boulder Clay - - - -	3 to 6
Sand with gravelly layers - - - -	6 to 4
Bed of stones and gravel - - - -	3 to 2
Marly Boulder Clay, like that above - - -	– –
	12

Mr. Enderby (the proprietor) supplied the following information: that the gravel appeared to thin out all round, its place being taken by the upper marl or clay which deepens to 10 feet at the cottage to the S.E.; that a black turfy bed was occasionally found below the gravel and resting on the lower marl, the surface of which was tolerably level; and that numerous bones occurred at the bottom of the gravel.

The gravel, which thus appears to have thickened lenticularly at this locality, consists almost entirely of flints and chalk pebbles in nearly equal quantities, the latter being picked out and burnt for lime; of other rocks, pieces of Red Chalk, Neocomian Sandstone, Quartzite, and Shelly (? Oolitic) Limestone occurred. Several large boulders of Basalt and a block of Red Felstone lay in the pit, having come, it was said, from the uppermost Boulder Clay.

The mammalian remains obtained from this gravel are determined by Mr. E. T. Newton to be *Elephas antiquus*, *Rhinoceros leptorhinus*, *Bos primigenius* (or Bison). Some of these are in Mr. Jabez Good's Museum at Burgh, together with a large stag's horn. Other specimens are in the Geological Museum, Jermyn Street, London.

The eminence on which the town of Burgh stands consists chiefly of brown sand, the depth of which in the centre is said to be about 20 feet; it is surrounded by Boulder Clay, that on the eastern slope being light coloured, greyish mottled with buff or brown; this probably underlies the sand at the top of the hill, but itself contains a bed of sand or silt from which water is obtained. This bed of silt or another one comes to the surface near Hawker's House N.W. of Burgh.

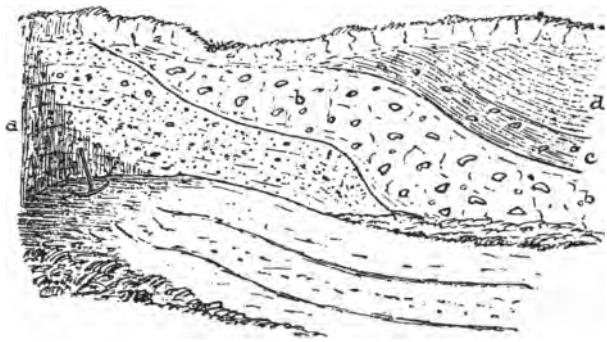
If the Boulder Clay to the east and north of Burgh is a separate and lower sheet than that to the west, then the intervening sand must here be discontinuous, and by rapidly thinning out must allow the two sheets of clay to come into apposition, for no line of division can be traced between

them. The "marl" which lies below the marsh-deposits east of Burgh is described as being of a yellowish or greyish white colour and very chalky (see sections in Appendix, p. 151), but as it is underlain by a liver-coloured clay there can be no doubt about its belonging to the Purple Clay series.

At Boothby Hall, north of Orby, there is another mound of sand similar to those already mentioned, and a longer ridge of the sand and gravel occurs at Hasthorpe. The edge of the latter was intersected in a sand-pit west of the farm, exhibiting sandy gravel rising to the surface from under a flanking mass of Boulder Clay and loam, as shown in the sketch Fig. 15.

FIG. 15.

Sketch in a Gravel-pit at Hasthorpe.



d Soft brownish sandy loam, 3 or 4 feet seen.
c Clean reddish-brown clay, passing into
b Stiff mottled brown Boulder clay, about 4 feet.
a Sandy gravel, irregularly bedded, 8 feet.

Another pit about a furlong to the northward also shows the thin edge of the Boulder Clay on the east side from under which a mass of sand and loam rises to the surface, the depth of this in the middle of the pit being about 10 feet; by digging at the base of this I found a thin layer of stiff and close argillaceous sand, tenacious enough to hold up water. Round the northern edge of this ridge a clean reddish loamy clay without stones or with very few occupies the surface and is seen in ditches.

At Welton, Boulder Clay of the Hessle type is exposed in the road-cutting south of the Church; it is reddish-brown, mottled, and streaked with grey, and containing the usual minute fragments of chalk; I also noticed small pieces of coal, flints, quartzite pebbles, and blocks of Neocomian "roach." The exposed part of the clay crumbles under the pick, but below it is tough and sticky. The well head near the Church seems to rise from beneath a bank of chalky marl, capped with brown clay, and at the Inn near by the well is said to be 27 feet deep through clay into gravel.

At a house about 200 yards N.W. of the Church Joseph Tutty, well sinker, dug 20 feet and bored 16 feet in clay without reaching gravel or getting water; yet solid chalk rises to the surface about the same distance due west of the Church and is seen in the road-cutting.

There can be little doubt that the Boulder Clay is here banked against an ancient cliff of Chalk, and that the water flowing eastward through the chalk is blocked by meeting this clay, and hence the spring thrown out near the Church. Similar springs occur at intervals along the line of junction to the northward.

Boulder Clay underlies Welton and Willoughby Woods and runs up into the valley crossing Shaddy's Walk, but does not enter the Claxby Valley. On the south side of the former valley and about five furlongs south of Claxby Church, coarse sand has been dug from a bed which seems to be banked against Chalk and to be overlaid towards the valley by Boulder Clay. A hole open in 1879 showed 10 feet of coarse quartzose sand like that of the Carstone, but very stiff and compacted, overlain by about 2 feet of dark purple-brown clay containing a few stones; this clay is said to thicken rapidly northward and it occupies the valley bottom, though the farm on the north side stands upon chalk, the well being 36 feet deep in that rock.

It will be less complicated if I now describe the sections and springs which occur at or near the junction of chalk and Boulder Clay as far north as South Thoresby and then proceed to notice the exposures in the country east of this line.

Well takes its name from the strong spring which rises at the entrance to the valley known as Well Vale. This spring appears to issue from solid chalk beneath a bank of reddish-brown clay; the water is always cool in summer and never freezes in winter; eastward there is either a very steep slope or a cliff of chalk, for the well at Mr. Cartwright's farm is 65 feet deep through Boulder Clay into the Chalk (see Appendix, p. 174). It will be noticed also that the boundary of the Boulder Clay is singularly straight as if the surface against which it rested was very steep; in some places one can almost be sure of standing with one foot on Boulder Clay and the other on Chalk.

There is no doubt, however, that the Boulder Clay was forced over the cliff edge on to the chalk land in some places, for small pockets and basins often occur on this ground which are filled with reddish loam, clay, and stones. One of these is intersected near the entrance to the chalk-pit west of Well North Farm; the N.W. face of the quarry shows a shallow basin, containing at the base a rubble of broken chalk mixed with hard clay and overlain by stiff reddish-brown loam with a few flints, total depth in the centre about 8 feet.

At Rigsby, Boulder Clay was seen N.E. of the Church at the end of the cart track marked on the map. The Church and the farmstead (Mr. Mason's) stand on chalk, but between the farm and the plantation to the N.E. a well was sunk 93 feet through stiff clay into sand and gravel. The distance between this and the edge of the clay is, I understood, about 150 yards.

North of Haugh there appear to be several swallow holes along the line of junction, where the water draining northward down the valley is absorbed and doubtless finds its way between the clay and chalk into the gravel which underlies the former.

Returning now to the neighbourhood of Willoughby it will be seen from the map that a long bank of sand and gravel is here intercalated in the Boulder Clay and stretches northward through Alford. I have used the term bank advisedly, for well-borings show that it does not extend far to the east or west of the tract along which it is exposed.

Gravel has been dug from shallow pits a quarter of a mile S.W. of the Hall and the gravel appears to pass eastwards beneath Boulder Clay, sand being found at a depth of 15 feet below Willoughby Mill. In the ditch by the farmstead two furlongs north of the Church gravel and sand were seen overlying dark chocolate-brown clay with chalk pebbles. In the field to the N.E. of this farm sand has been dug and a pit there exposed 6 feet of false-bedded sand with layers of small pebbles passing up into a sandy loam. The sand is said by the farmer to rest on dark purple clay. Sand and gravel are seen continuously along the deep ditch which runs northward through the fields.

Bonthorpe is on Boulder Clay, said to be about 40 feet deep before sand is reached, but southwards loam and sand come on suddenly without any change of feature and occupied the ground round Sandfield with a depth of 15 to 16 feet.

At Farlsthorpe to the northward there is a brickyard south-east of the Church, where an interesting section was found in 1879; that at the S.W. end of the pit was as follows:—

	feet.
Yellowish-brown clay, with a layer of small calcareous concretions at the base ("ginger")	2
Mottled drab and yellow silt, with a thin layer of turfy matter at the bottom	3
Soft bluish silty clay	2
Brown marly clay below	—

The layer of turf is hard and shaly and looks as if there were seaweeds in it. These silts occupy a hollow thinning out to the N.E. and near the kiln the section is different, as below:—

	feet.
Disturbed soil with remains of bluish silty clay	2
Silty-clay, mottled bluish-grey and yellow, full of stones with pockets of gravel which descend into clay below	3
Solid chocolate or purple-brown clay full of stones, chalk preponderating (called "marl" by workmen)	7

The stones are picked out of this clay and it is then ground up and made into bricks; the stone heap is quite a collection of rock-specimens. I noticed the following: red and white quartz pebbles, quartzites, red granite, syenite? porphyritic basalt, black basalt, purple conglomerate like Scotch Old Red sandstone, shelly limestone (Jurassic), coal (many small fragments), Carboniferous limestone, and several black flints with a very thin white coating (probably from Flamborough); a similar flint obtained from the foreman has a coating of yellow iron pyrites instead of the usual white rind. Many of the stones are striated.

The foreman stated that they had once dug through this "marl," finding it about 20 feet thick and underlain by dry yellowish sand, only just touching the latter as they were afaid of water coming in. This sand bed must be at about the same level as the sand and gravel which comes to the surface west of Farlsthorpe; if it is the same bed this has clay of the "purple" type above it as well as below, and must not be identified with the so-called Hessle gravel. That to the N.E. of the village may be in the Hessle clay, but no sections were seen.

At Well Carrs there are large overgrown ballast pits, whence ballast was obtained for constructing the railway, but no section is now visible.

At the brickyard half a mile S.S.W. of Alford Church what appears to be a continuation of this gravel is certainly overlaid by a Boulder Clay of the Hessle type, but this is a narrow tongue, the relation of which to the gravel on the north of it is not known for certain. The section at the south end of the brickyard is as follows:—

	feet.
Vegetable mould	1
Yellow sandy loam	4
Stiff mottled brown clay	2

The loam thins out to the north and gravel is seen below Boulder Clay in the deepest excavation, thus:—

	feet.
Vegetable soil	1
Brown Boulder clay, mottled with grey	6 or 7
Chalky gravel, full of water	2 ×

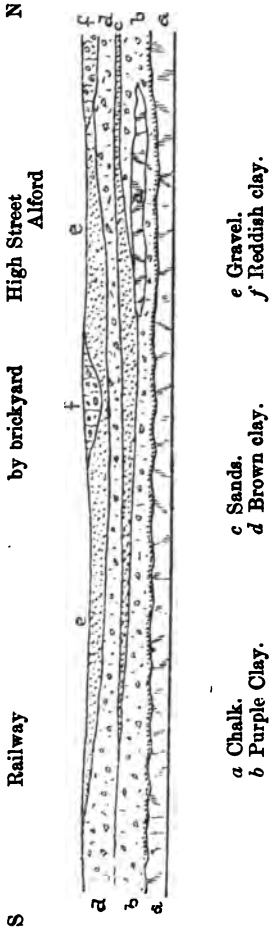
About 75 per cent. of the stones in the gravel are chalk, but flints, quartz pebbles, and other rocks, made up the remainder; pieces of coal were frequent often in groups of a number close together. At the house by the entrance to the yard the thickness of the Boulder Clay is said to

be more than 20 feet, but I am inclined to think that it lies in a hollow or trench scooped out of the gravel, that which occupies the surface to the north and south being continuous beneath it. If so, a section from North to South through the beds beneath Alford would appear as in Fig. 16.

FIG. 16.

*Diagram section through Drift below Alford.**

Hor. scale 3 inches to a mile. Vertical scale 200 feet to an inch.



The gravel on which Alford stands seems to vary in depth; in the new road, about a quarter of a mile S.W. of the Church, it is said to be 24 feet deep, but along the High Street and in the Market Place it is only from 8 to 10 feet. It continues to occupy the surface as far as Fotherby and Ailby, and seems then to pass underneath Boulder Clay, but reappears here and there at the surface near Ailby, Saleby, and Aby. The outlying patch at High Bibers, between Bilsby and Saleby, is at a much higher level, and is probably a different bed.

Gravel and sand also occupy a considerable surface area between Aby and Belleau, but their position in regard to the surrounding Boulder Clays is uncertain, though I am inclined to think they pass under that to the

* The boulder of Chalk near the north end of the section is inserted on the strength of the evidence given by wells, see pp. 148 and 149 of Appendix.

eastward, which is of the Hessle type. (See Section 2, in Plate at the end of the volume.) The point acquires importance from the fact that the gravel contains marine shells, and that Aby is the only locality in Sheet 84 where I have found shells in the Glacial series.

There are two gravel pits, one about five furlongs S.W. of Claythorpe Station and one about the same distance due south of that station, but the latter only is now worked continuously. The section here in 1879 was as follows:—

	feet.
Brown sandy soil - - - - - - -	1 to 2
Fine gravel with irregular layers of sand containing shells -	6
Gravel with larger stones (water at bottom) - - -	4

The gravel contains the usual assortment of rocks, granite, gneiss, felstone, limestone, &c., but flints and chalk pebbles are in a large majority, the fine gravel consisting chiefly of chalk with some bits of red chalk. Some of the larger pebbles of chalk contain the ends of Pholas burrows, like those that may be found on any beach above a chalk scar at the present day; others are bored by the burrowing sponge.

The shells in the sand seams are mostly worn and fragmentary, but perfect specimens of *Tellina balthica* are common. Mr. C. Reid has supplied me with a list of the shells he found here in 1883, which is fuller than my own list.

List of Fossils from Aby, near Claythorpe.

Ostrea edulis (fragments and perfect young).
Pecten sp. (one fragment).
Mytilus edulis (fragments).
Cardium echinatum (one fragment).
——— *edule* (fragments).
Cyprina islandica (hinges).
Venus gallina (several large fragments).
Tellina balthica (perfect).
——— *lata* (hinges and fragments).
Mactra solida (nearly perfect).
——— *subtruncata* (perfect).
Solen siliqua? (fragment).
Corbula gibba (one, perfect).
Mya truncata (fragments).
Pholas crispata (fragments).
Purpura lapillus (one fragment).
Trophon Bamffius (one fragment).
Natica sp. (one eroded specimen).
Dentalium entalis (two nearly perfect).
Balanus crenatus (perfect valves).
——— *porcatus* (perfect valves).

Gravel and sand extend continuously from Aby through South Thoresby to Calceby by the side of the Calceby Beck.

The chalk-pit near corner of road a quarter of a mile N.E. of Thoresby Hall intersects a hollow which has been scooped out of the chalk and filled up with drift; this was clearly exposed at the east end of the pit in 1879; the basement bed resting on the chalk was here a dark brown clay full of chalk pebbles, and overlain by coarse gravel with a matrix of ferruginous sand; some of the chalk blocks in this gravel are of considerable size. The clay thinned out against the chalk and only lined the bottom of the hollow, which was 6 or 7 feet deep under the hedge.

Gravel has been dug from pits three furlongs S.W. of the Church, but not recently; the stones are chiefly chalk and flints, one pebble of the former being bored by Pholades; lumps of red and pink chalk are not uncommon, and some containing *Belemnites* are clearly from the basement

rock which crops out opposite Calceby. I also noticed a lump of sandstone like that of the Spilsby Sandstone.

South of the above and a quarter of a mile N.E. of Calceby Church is a sand-pit which has been worked for many years, and is from 20 to 25 feet deep. The material is a soft clean light brown sand, regularly stratified with numerous thin seams of stiff brown clay and occasional layers of coarser sand, containing small pebbles of chalk, flint, grit, and other rocks; in one place the sand contained many pieces of soft coal or lignite, and specs of carbonaceous matter were common throughout, but I could not find any shells. At the top of the hill there is a loamy clay, something like Boulder Clay without stones, capping the sand.

On the opposite side of the Calceby Beck there seems to be more Boulder Clay than sand or gravel, but two irregular patches of the latter occur near Swaby, which appear to be separate deposits parted by a layer of Boulder Clay.

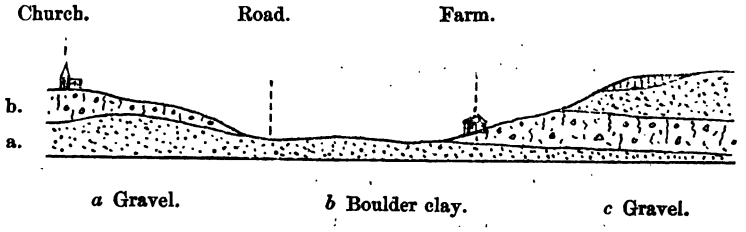
The high ground east of Swaby is capped with gravel, and a small pit on the western edge of this, above Mr. Creswell's farm, exposed the following section:—

	feet.
Hard sandy clay with stones - - - - -	3
Loose chalk gravel, with beds of fine sand and coarse gravel at the base, irregularly bedded - - - -	8
Dark brown Boulder Clay (touched) - - - -	1

At the bottom of the bank by the farmstead I found a tough brown Boulder Clay overlying gravel composed of small chalk pebbles, and water is thrown out from this gravel behind the sheds. The new farmhouse stands on the Boulder Clay bank, and the well is sunk through six feet of sandy clay into hard sandy gravel (17 feet). At the entrance gate running sand was found, but in the bank above and at the church there is Boulder Clay, so that the facts appear to warrant the interpretation suggested in Fig. 17.

FIG. 17.

Section across Valley at Swaby.



a Gravel. *b* Boulder clay. *c* Gravel.

By the roadside south of the Church is a small pit from which sand is said to have been extracted, but there seems to have been clay at the surface. At the corner of this road opposite the new schools a well had been dug 12 feet, through soil, (1 foot), marl mixed with chalk stones (2 feet), soft sand (9 feet), so that there seems to be here a mound or bank of sand wrapped round and partially covered by Boulder Clay.

The mass of Drift above described has blocked up the ancient valleys of the two little becks which run north and south of Swaby, and has obliged them to excavate new channels through the chalk (see map, p. 122). The Boulder Clay runs for some distance up both these valleys (see published map), showing them to have been in existence before the date of its formation, though it would not be safe to consider them as pre-glacial on this account.

At Walmsgate the westernmost farm stands upon a high bank or mound of Boulder Clay, which seems to block the valley; the ancient course of

the stream was probably on the northern side of this, but it now runs in a deep ravine excavated between this mass of Boulder Clay and the solid chalk on the south. The Boulder Clay appears to rest on a bed of gravel (see Appendix 174), which is exposed on the lower ground to the west; this field is full of springs, but on the north side of it some holes have been dug for sand, which has been proved to a depth of 10 feet beneath a rubble of chalk, which looks as if it had fallen from a cliff or steep slope of chalk.

Returning to Calceby and ascending the beck the observer will find it flanked on both sides by glacial clay and gravel, which entirely conceal the outcrop of the Neocomian beds and are banked up against them to a considerable height at South Ormsby; the exposures are so few, and the masses of gravel come on so suddenly, that the lines engraved on the map must be taken as very rough indications of their limits.

Gravel and sand seem to set in suddenly to the south-east of Ormsby, and form a thick mass running up the deep valley in which Brinkhill lies, while the valley near Ormsby Wood is chiefly filled with Boulder Clay. At the cottage opposite Ormsby Church a well was sunk for 45 feet through stiff stony clay with veins of sand. The ditch on the west side of Ormsby Wood is deep enough to show the composite nature of the materials which make up these mounds of Drift. At the top there is a rubble of chalk stones set in a matrix of clay, and evidently derived from the chalk bank above; lower down there are beds of yellow sand and loam, with patches of reddish-brown Boulder Clay, and half way down the slope there is stiff brown Boulder Clay full of chalk stones. The same clay occupies the bottom of the valley for some distance, but at the eastern end there is a mass of sand and gravel banked against the slope. A spring is thrown out near the copse a quarter of a mile N.E. of the farm, and the banks of the watercourse show chalky gravel, dark green sand, and reddish clay, all apparently bedded together in confused masses.

The valley west of South Ormsby is similarly filled with glacial deposits. The north side of Ormsby Park consists of Boulder Clay and loam, while south and west of the Hall there is gravel and sand which widens out westward and forms a tract of considerable superficial extent between the Park and the village of Tetford.

In the ditches north of Harden's Gap a peculiar kind of gravel is seen, consisting of lumps of white and red chalk, Neocomian ironstone, and other rocks from the immediate neighbourhood, embedded in a dark sandy matrix, the whole being compacted into a hard mass which looks like Boulder Clay from a little distance; eastward it passes into chalky gravel with beds of soft loamy sand.

At the cottage, three-quarters of a mile N.N.W. of Ormsby Hall, the occupier states that the well was dug through 16 feet of chalky gravel into sand. Mr. Grantham's farm, 7 furlongs N.W. of Ormsby Hall, stands on a strip of clean sharp sand, about 20 yards wide, between the chalk and the chalky gravel outside. The same gravel, composed of small chalk pebbles embedded in a yellowish earth or loam, runs up into Holster Dale and westward below the chalk escarpment. Some of the ditches here expose a bed of stiff brown clay containing stones and overlaid on the south side by sand and gravel which pass beneath the alluvium.

North of Tetford the material is chiefly sand, yellow, brown, or dull green, and evidently derived from the underlying Spilsby sandstone, but in the hollow south of Tetford Wood chalky gravel is seen again, and a hard calcareous loam by the roadside about three furlongs N.W. of the Church. South and west of this the Neocomian sandstone comes to the surface. The origin of the Ormsby and Calceby Valley will be discussed in a future Chapter. In this I confine myself to describing the glacial deposits.

Returning now to the entrance of the latter valley at South Thoresby, I proceed to describe the sections met with in the main mass of the Boulder Clays northward.

At Belleau fine springs of water rise to the surface between the Church and the Hall, and probably mark the continuation of the cliff line already

mentioned. The Boulder Clay mantles the whole surface, however, and climbing the slope of chalk it caps the high ground south of Megrim Hall, its thickness in the well at the farm half a mile west of Belleau being 12 feet. What is still more curious a narrow strip of Boulder Clay runs up from the valley north of Swaby on to the top of the hills near Burwell Park, where it unites with the main mass enveloping the outer slope of this ridge.

In Burwell Park it has no great depth, and is in some places little more than a clay soil on the top of the chalk (see section of chalk-pit at Muckton, p. 68). The only noteworthy section hereabouts is in a small outlying patch of sand, gravel, and loam half a mile S.W. of the Hall. A pit in the field behind the gardener's house shows coarse chalk and flint gravel at the west end and hard compact laminated sand at the east end in a hole 6 feet deep. The chalk-pit near the park gates north of the above cuts through a bank of red-brown loamy clay, resting on a rubble of broken chalk, and dipping down into the hollow which crosses the road.

At Authorpe, three furlongs N.E. of the Church, there is a brickyard, belonging to Mr. Turner of Alford, in which a good section of the upper clays is exposed, as given below :—

	feet.
Yellowish loamy soil, with pebbles at its base - -	2 to 3
Reddish-brown clay, mottled, and streaked with grey -	6 ,, 8
Stiff loamy purple clay without stones and laminated in places - - - - - - - -	5 ,, 6
Purple clay without streaks and with few stones, seen for	0 ,, 6
	22

The upper clay is full of chalk, flints, and other stones, as well as small sandy particles, which give it a gritty feel, and it burns to a red brick. In other parts of the pit there are layers of yellow-brown sand which cut out a portion of this clay and rest on the clean purple silty clay, the top of which is always about 10 feet from the surface. The purple clay here contains very few stones and is used for making square tiles and drain-pipes, which are of good quality ; it burns reddish, but not so deep a red as the upper clay, and in one place they found a clay which burnt white.

Mr. Turner informed me that in boring a well here he found the thickness of this purple clay to be 14 feet, with a white marl below underlain by gravel and sand (see Appendix, p. 150).

At South Reston there is another brickyard disclosing a similar section, seen in 1881 as below :—

	feet.
Dark brown Boulder Clay, streaked with grey, and containing a lenticular bed of false-bedded sand - - -	9
Dark purple-brown laminated loam - - - -	2
Dark purple-brown Boulder Blay without streaks - -	15
Brownish sand, said to be found below for - - -	3

The upper clay is like that at Authorpe and burns red; the maximum thickness of the sand is 2½ feet, but it is entirely absent at the north end of the pit. The lower clay contains many large boulders near the bottom ; it makes nearly white bricks, and there is therefore some chemical difference between the clays (see analyses given on p. 77).

At Little Carlton, in the pond below the mill, 2 feet of Hessle Clay are seen below 3 feet of alluvial loam. About a quarter of a mile north of the mill, a cross drain from the road to the beck shows a lenticular bed of sandy gravel, intercalated in clay of the Hessle type, the section being as below :—

	feet.
Reddish-brown clay, with grey streaks - - -	5 to 4
Sandy gravel - - - - - -	2 ,, 1
Clay identical with that above - - - -	0 ,, 2

Total depth of the ditch about 8 feet.

At North Reston sand has been dug near the Church, and another larger patch of sand and loam occurs to the westward. In the bank of the stream half a mile west of the Church I found the following exposure :—

	feet.
Sandy soil	2
Yellow and brown sands	5
Purple-brown clay	4

This last is a stiff homogeneous and somewhat plastic clay; it is certainly not the Hessle Clay, but is like the lower bed at South Reston. Hessle Clay, however, is seen in the ditches near the railway to the southward overlying yellow sand, which here and there comes up to the surface. This, however, is lower ground than where purple clay was seen, so that the surfaces of the beds must be very irregular.

Hessle Clay was also seen in the ditch by the road side half a mile S.E. of Legbourn Church, overlaid by brown laminated loam and light yellow sand, the two latter about 4 feet thick. This patch of sand is therefore in or above the Hessle Clay, as are also the two smaller patches to the northward.

Another more extensive band of gravel lies to the west of Legbourn. A ditch running north of the mill by the Abbey, and cleared out in 1881, showed Boulder Clay at the south end, apparently overlaid by gravel to the north, but this junction was not very clear. In the deep ditch running beside the road near the railway station, the gravel is seen to be composed of rounded water-worn pebbles, among which are many of quartz and quartzite, embedded in a clean brown sand. Similar gravel with beds of sand passes northward round Braken Hill.

In Kenwick Park there is a great mound of Boulder Clay, about half a mile S.E. of the Hall, which blocks up the natural drainage from the chalk slopes, and turns it southward to Cawthorpe.

The excavation of the curious valley at Cawthorpe will be explained hereafter (see p. 125). Here I need only mention that a strong spring issues from the chalk immediately below the Church, but a few yards down the watercourse to the N.E. Boulder Clay comes on suddenly. The explanation of this I take to be that the water percolating through the chalk is blocked by a mass of Boulder Clay resting against a buried cliff, the line of cliff running just east of the Church, and that the water is consequently thrown up to the surface.

As at Belleau and Burwell the Boulder Clay here surmounts the cliff, and the old chalk-pits south of the Church show the following section:—

	feet.
Brown Boulder Clay	9
Chalk rubble (the "croy" of well sinkers)	2
Chalk with flints	10
Chalk? without flints (hidden by talus)	15

It is clear that Boulder Clay once extended continuously up the valley to the westward, and a long strip still remains in the hollow by Haugham Pasture. Not only so, but outliers of the same clay are found on the summits of the hills both to the northward and southward. It will be convenient therefore to describe these in the present connexion.

Large quantities of gravel have been raised from pits about half a mile east of Haugham Church, the beds exposed here in 1879 being as follow:—

	feet.
Brown stony loam, running into pockets	4
Coarse gravel of flints and chalk stones massed together without any definite bedding	6 to 8
Smaller gravel in irregular layers, passing down into a coarse flint gravel	9 „ 10
Chalk-floor exposed in one place	—
	20 to 22

The matrix is a chalky sand and some of the layers in the middle are stained black with oxide of manganese. A few boulders of quartzite and other rocks occur. The stony loam at the top is almost a clay, and seems to pass northward into Boulder Clay.

In the chalk-pit three-quarters of a mile south of Haugham, a remnant of Boulder Clay is seen occupying a shallow basin. The barn to the S.W. stands on a patch of brown stony clay, and a similar brown clay with stones lies on the slope of the hill east of Maidenwell, and gravel has been dug at the west end of this patch, where it appears to overlie white chalky Boulder Clay (see p. 75). The old pits S.E. of the farm are 15 or 16 feet deep, and appear to have been dug in gravel with layers of brown sand and loamy clay, but the first is exhausted and the pits are overgrown.

The hill west of Haugham is capped with a red-brown clay, passing down into a rubble of chalk mixed with clay, as seen in a chalk-pit on the north side of the hill five furlongs W.N.W. of Haugham Church. On Orgarth Hill there are many excavations from which gravel has been dug, and one of these on the north side exposed a stiff cream-white marly clay without stones.

The long strips of Boulder Clay which remain in the valley bottoms near Tathwell seem to be of the Hessle type. Tathwell Church stands upon an isolated mound of clay, and the stream runs between this and a cliff of chalk, from the base of which strong springs are thrown out.

The sand-pit, half-a-mile N.E. of Tathwell, shows about 10 feet of yellow sand, with layers of chalk pebbles, small flints, and pieces of coal, dipping regularly westward.

In a pond by the farm, a mile E.N.E. of Tathwell, several feet of typical Hessle Clay were seen, reddish-brown with grey streaks, and full of small bits of chalk and coal; this hill must be about 250 feet above sea-level.

The Coxey Hills to the north of Tathwell are not so high, but they also are capped with Boulder Clay, and there can be little doubt that this originally formed a continuous sheet, completely investing these hills and filling up the valleys on either side. The western slopes have been denuded, but the Boulder Clay is still continuous down the eastern slope into the valley of the little beck which rises near the house called Dexthorpe. In a deep ditch at a point about three-quarters of a mile W.S.W. of Louth Grange, I found a dark purple-brown clay exposed with bluish stains on the joint surfaces; it contains a few large boulders, but very few smaller stones, and is in every respect like the lower clay of the brickyards. Elsewhere the clay is more of the Hessle type.

About Raithby and Hallington the clay is also chiefly Hessle, but in the bank of the stream where it is bridged by the railway east of Hallington there is the same dark purple-brown clay with less chalk in it than in that of the Hessle type.

Boulder Clay of one kind or the other occupies the bottom of the Withcall and Hallington valley from end to end, passing eastward along the depression to the south of Louth, which was its ancient debouchure (see Fig. 6, p. 51, and map, fig. 24.

A good section of the clays is exposed in a brickyard about three-quarters of a mile S.E. of Louth Church. Here reddish-brown clay with grey streaks is seen to pass down into purple-brown clay without the intervention of any layers of loam or sand. There is a complete passage from one to the other; the upper clay is full of chalk, the lower contains fewer stones, and is the best suited for brick-making. The depth of the pit is 18 feet, and the foreman states that they have dug 10 feet deeper into the same purple clay.

A brickyard at Stewton, a mile and three-quarters east of the above, shows a passage of a different kind. The section seen here in 1882 was as follows:—

	feet.
Loamy soil - - - - - - - -	2
Reddish-brown clay with small chalk stones, including lenticular seams of loamy sand and silt - - - -	4

	feet.
Yellowish-brown sand with intercalated veins or tongues of reddish clay	½ to 1½
Dark purple-brown clay with many chalk pebbles and large boulders of other rocks (some striated)	6
Same clay dug for 8 feet lower, according to the foreman.	

There is no sign of ny break or unconformity; on the contrary, the sand bed seems to dovetail into both the upper and lower clays, and in one place there was reddish clay underlying the sand and passing down into the purple clay; moreover, the lower clay varies in colour: in some places it is a uniform purple-brown, but in others the planes of fracture are stained dark greyish-blue; those in the upper clay are stained light-grey or ash-colour as usual. When burnt the upper clay is reddish and the lower is whitish.

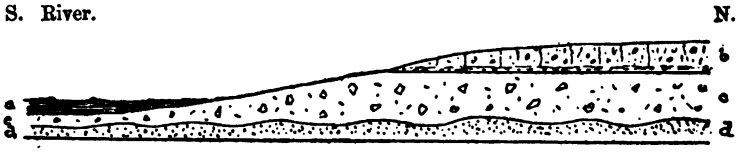
Returning to Louth a similar succession can be seen in the brickyard (Mr. Ryley's) near the railway, half-a-mile east of the Church. At the time of my visit the section was not clear, one corner only showing soil and reddish-brown clay, 6 feet; sand and silt, 2 feet; with dark blue-purple clay below. The foreman, however, informed me that on the south side where the ground rises the section was as follows:—

	feet.
Soil and red clay	12
Sand and pebbles	2
"Blue" clay	18 to 20
Sand and gravel, with water	—

On the north side near the road there is gravel at the surface, overlying red clay, and no sand between the two clays.

FIG. 18.

Section through Brickyard in James Street, Louth.



a Alluvium. *c* Purple Clay.
b Hessle Clay. *d* Sand in Purple Clay.

At another brickyard in James Street, a quarter of a mile west of the railway station, I obtained information confirmatory of the above. The pit is a large one, and the north face gives a clear section of the following beds:—

	feet.
Reddish-brown clay, with the usual characters, for 12 feet, passing down into a hard sandy and stony loam, about 2 feet thick	14
Purple-brown clay, with very few stones, seen for	10

The base of the red clay is nearly horizontal, and as the ground falls towards the river, the purple clay comes to the surface on the slope. The foreman states that when the yard was first opened this was the only clay found, that its full thickness is about 20 feet, and that below it there is sand full of water. He says also that the surface of this sand is irregular, and that they reach it sooner in some places than in others; he has not dug further than 4 feet into the sand.

A section through this brickyard from the river northwards and down to the level of this sand-bed must be as represented in Fig. 18.

It is clear that the River Ludd has cut its channel completely through the Hessle Clay, and the lower parts of Louth round the Market Place and the Church probably stand upon the Purple Clay. I have seen purple-brown clay thrown out from excavations near the Market Place. These facts are reasons for retaining the Hessle Clay as a sub-division of the Glacial series, though a comparatively unimportant one; there is no evidence of any unconformity between the clays.

Boulder Clay can be traced up the valley of the Ludd for some distance west of Louth, and also up the valley that leads to South Elkington, but does not enter the valley below Hubbard's Hill, although that hill is capped by an outlier of gravel and Boulder Clay. Boulder Clay also spreads over the high ground north-west of Louth (for section in the Lime Kilns, see p. 58).

That the clay on the hills was once continuous with that in the valleys is proved by the two being still actually in communication near South Elkington. The clay is here bedded into an old hollow or tributary valley, and a brickyard has been opened in it by the side of the road three-quarters of a mile S.E. of Elkington Church. This yard exposes about 6 feet of dull purple-brown Boulder Clay, streaked and mottled with bluish-grey; it contains many stones and Boulders,—Chalk, Flints, Basalt, Felsite, Compact Limestone, Oolite Limestone, Septaria, Quartzite, &c.; many of these are striated. No trace of Red Hessle Clay was seen, but the soil consisted of a sandy loam or rainwash, thickening from 1 to 4 feet down the slope; and in the middle of the pit a bed of greenish sandy clay came in between the two, lying apparently in a shallow basin worn out of the Boulder Clay.

In the plantation S.E. of this brickyard there are old gravel pits more than 30 feet deep, but much overgrown; the upper part is a fine gravel consisting of angular fragments of flint and chalk with thin layers of sand and sandy loam; the lower beds are a coarse gravel with angular flints as large as a man's fist embedded in a matrix of coarse brown sand.

To the west of South Elkington the ancient continuation of the valley is blocked up with mounds of sand, gravel, and Boulder Clay, which seem to be flanked and partially covered by a sheet or mantle of Red Hessle Clay, and this again in one place is covered by sand. Such an arrangement makes detailed mapping of the surface exposures almost impossible, but the beds themselves can be studied in the numerous gravel pits which are open between Elkington and Welton.

The first of these is on the top of the hill about three furlongs S.S.W. of Elkington Church, and the section exposed in 1882 was as follows:—

	feet.
Soft red-brown sand and loam	4
Red-brown sandy clay, containing small bits of chalk, coal, and other stones	4
Coarse flint gravel obscurely stratified in a matrix of coarse quartzose sand	15

The workmen state that the gravel is from 18 to 20 feet in depth and that it rests on chalk.

The adjoining pit to the N.W. is 12 feet deep in clean stratified sand, which seems to be a continuation of that overlying the Hessle Clay in the first pit. The bedding of the sand is irregular and curvilinear; it contains some coarser layers composed of small pebbles of chalk and coal, and some lenticular patches of fine coal-dust; there are also thin beds of hard loam which might result from the erosion of Boulder Clay; that the sand was accumulated by the action of varying currents is very apparent: it now forms a high ridge running east and west with a deep hollow or valley on the northern side, the bottom of which may be on Boulder Clay.

Another pit, half a mile W.S.W. of Elkington Church, is dug in a mass of gravel exposed on the slope of the valley with clay above and below, the eastern face showing that the clay wraps over a mound or ridge of

gravel, and descends into the valley on the south. This clay is of the Hessle type, streaked with grey, and full of small grains of quartz sand.

North of this, and about five furlongs due west of Elkington, there is a larger pit, from which great quantities of gravel have recently been raised. The section in the middle of this was as follows in 1882 :—

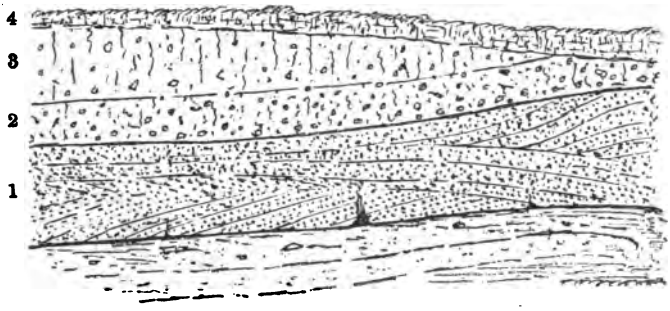
	feet.
Soil, loamy clay	1
Reddish-brown clay of Hessle type, containing much chalk and some large flints	7
Hard yellow-brown sandy clay, with a ferruginous layer near the base containing brown-coated flints	1½
Unstratified rubble of small angular flints in a matrix of hard sandy clay	6
Roughly stratified flint gravel in a sandy matrix	16
Similar gravel with contorted bedding	10
	41½

The stratified gravel contains some knots or patches of stiff loam and lenticular beds of sand. Out of 55 pebbles, 48 were flints, 5 chalk, and 2 carnelian; a few quartzites also occur. Some of the beds contain black oxide of manganese in the interstices. Mr. M. Staniland, who analysed some of this at my request, found the powder to be a pure oxide of manganese.

Another pit, about three-quarters of a mile west of Elkington, shows a similar set of beds, of which Fig. 19 is a sketch taken near the entrance of the pit.

FIG. 19.

Sketch in a Gravel-pit west of South Elkington.



	feet.
4. Brown clayey soil	1 to 3
3. Stiff brown Boulder clay of Hessle type	10
2. Hard stony clay, passing down into an unstratified mixture of clay and stones	4
1. Roughly stratified flint gravel	12
	27

The same gravel stretches westward into Sheet 83, and is surrounded on all sides by Boulder Clay of the Hessle type. A pit just on the edge of the map exhibits a section similar to those above described and 32 feet

in depth, the upper part of the gravel consisting of broken flint fragments set in a matrix of sandy clay or loam, and the lower part of larger flints enclosed in coarse quartzose sand; the former is capped by 5 or 6 feet of Hessle Clay.

North of this pit Hessle Clay can be traced to the foot of the hill; it is then succeeded by a yellowish-grey clay or marl, which looks as if it contained finely divided calcareous matter and may have been formed from the materials of the Chalky Boulder Clay which caps the hill above. The same silty yellowish marl occurs below Mr. Vessey's house (Welton Hall), in Sheet 83, where it seems to occupy the same position between white chalky Boulder Clay (seen under the greenhouses) and the brown Hessle Clay on the slope below.

Returning to the main mass of Boulder Clay east of the Chalk Wolds, it is sufficient to state that it forms a broad tract of undulating country, with elevations or ridges which are perhaps from 50 to 60 feet above the sea level. (See Section 1 in Plate at the end of the volume). Sections of the Hessle Clay may be seen everywhere in the ditches and along the courses of the streams which drain this district, but they are seldom deep enough to show anything of interest. The only one worth noting was in a deep open drain running nearly north and south about three-quarters of a mile west of Covenham St. Mary; in this the following section was observed:—

	feet.
Brown clay soil	1
Reddish-brown Boulder Clay, with grey markings	5 to 6
Loamy clay full of stones, with layers of yellowish sandy loam and a layer of black shaly clay at the base	1½
Reddish brown clay with bluish markings, darker than the top clay, but very similar	2

In the black clay I found fragments of quartzite and micaceous schist. A few yards to the south this and the loams seem to thin out, allowing the two sheets of Boulder Clay to come together. By the farm to the north-west there is loam at the surface which may possibly be an extension of the same bed.

It is also noteworthy that patches of gravel and sand occur at intervals between Louth and Ludborough; these appear to be portions of a long ridge or bank underlying the uppermost sheet of Boulder Clay, and running nearly parallel to the line of the chalk slope, which is also probably a line of buried cliff. Gravel was dug from pits half a mile S.S.E. of Fotherby, and used in the construction of the railway. At Utterby the material is chiefly sand and loam. The small patch S.E. of Ludborough is gravel, but the village stands upon sand and laminated loam.

The brickyard south-west of Ludborough is interesting, as showing a gradual passage from Hessle into Purple clay. The section exposed at the west end of the pit in 1882 was the following:—

	feet.
Clean stiff loamy clay	2
Yellowish sandy loam	4
Reddish-brown clay with grey streaks and full of small stones passing down into the next	about 6
Dark purple-brown clay with bluish streaks in the upper part, but compact and uniform below	4
	16

Along the east side of the pit the sandy loam passes into stratified sand with layers of loam, and in this sand I was informed that a number of bones of various animals were found about 20 years ago. There is a complete passage from the red clay into the purple; it is the faces of the

joints and cracks in the red clay which are stained grey and give it a streaked appearance, and where these pass into the purple clay the staining is blue-grey; the colour seems to be due in some way to the percolation of water. The foreman describes the lower part of the clay as "blue," and says they formerly dug to a depth of 50 or 60 feet from the surface without finding any change. He also informed me that at the cottages, three furlongs south of the yard, a well was bored to the depth of 96 feet entirely through clay, without reaching the chalk and without obtaining water. This is close to the chalk slope, and only about one furlong from the edge of the Boulder Clay. For the depth of other wells on the Boulder Clay area, see Appendix B.

CHAPTER VIII.

POST-GLACIAL DEPOSITS.

§ 1. Revesby Gravel.

It was mentioned in the last Chapter that the Boulder Clay between Hagnaby and Stickford passed westward beneath sand and gravel, which was apparently of later date. This sand and gravel is continuous with a broad strip of similar material, which extends westward by Kirkby and Revesby into Sheets 83 and 70, where it spreads out into a still wider sheet by Mareham and Tattershall.

Whether the whole of this gravel is newer than the brown Boulder Clays may be open to question; the eastern portion has certainly been re-arranged by the waters of the Hagnaby Beck, and it might be argued that it is only this portion which overlies the Hessle Clay, and that the mass of the Kirkby and Revesby Gravel is of the same age as that Boulder Clay. Its mode of occurrence is certainly more like that of a marine beach gravel than of a river gravel, but the finding of marine shells in it would not prove it to be of Hessle age, for it may belong to the Post-glacial marine gravels which are found elsewhere along the borders of the Fenland, notably between Swaton and Bourn in Sheet 70. On the whole I am inclined to correlate the Revesby Gravel with these marine gravels, and to regard it as a Post-glacial deposit, newer than the Hessle Clay and older than the mass of the Fen and Marsh deposits.

Local Details.

Gravel has been dug in several places near Revesby, and its depth is greatest along the northern part of the tract; southward it becomes thinner, and the Catchwater Drain appears to be everywhere cut through sand or gravel into the underlying clays.

At Thuttilhill gravel has been dug in the field east of the farm to a depth of 15 feet, but when seen in 1878 the pit was only 8 feet deep, in small sandy gravel, with a few larger flints. This must be banked up against the chalky Boulder Clay which comes to the surface close by. At the cottages on the north side of the road west of Thuttilhill the well was said to be 30 feet deep, through sandy soil into blue clay.

Between Thuttilhill and Kirkby gravel has been dug in several places. It consists chiefly of broken flints with a few quartzite pebbles, and is mixed with much sand; the depth here is only from 4 to 6 feet, and the workmen say it rests irregularly on a blue clay with chalk stones. I was also informed that on the north side of the road it was much thicker, *i.e.*, from 10 to 12 feet.

At Mr. Orry's near the corner of roads, half a mile south of Kirkby Church, the well is said to be 30 feet, chiefly through sand and gravel, with

blue clay at the bottom, while just north of the village white chalky Boulder Clay is seen at the surface, so that the gravel must have a very irregular base.

East of Kirkby Church the material is chiefly sand, which is seen in the deep ditch by the roadside, half a mile E.S.E. of Kirkby Church.

Sand and fine gravel are visible at many points along the course of Hagnaby Beck, but end abruptly on the north side of the road near Hagnaby; northward, however, sand sets in again, and occupies some space in the valley and on the slopes near Bolingbroke. This sand has evidently been washed down from the neighbouring hills.

About Moorby and Claxby there are occasional patches of light soil on the Boulder Clay ground. They appear to be the result of the weathering of the Boulder Clay (which chiefly consists in the dissolving away of the chalk constituent), and can hardly be considered as constituting a distinct post-glacial formation. The three patches south of Miningsby are of similar material; in none is the sand more than 3 or 4 feet deep.

§ 2. The Marsh and Fen Deposits.

General Description.

The Lincolnshire Fenland is too well-known to need description: Sheet 84 includes part of what is known as the East Fen, between Stickford and Wainfleet.

The level tract of varying width which intervenes between the coast-line and the Boulder Clay plateau is popularly called the Marsh or Marshland. It is in reality an extension of the Fenland; the two districts are absolutely continuous with one another, and the clays and silts which compose the Marshland are of exactly the same nature as those which form so large a portion of the Fenland. Beds of subterranean peat, which are of such frequent occurrence beneath the Fenland, are also found beneath some parts of the Marsh, and on more than one horizon. It is clear, therefore, that the two districts were formed exactly in the same manner and at the same time; and, to complete the parallel, I may mention that certain portions of the Marshland are locally termed Fens, such as Farlsthorpe Fen, Carlton Fen, Conisholme and Grainthorpe Fens.

The average level of the surface, both in the Fen and Marsh, is 10 feet above ordnance datum; in some places it is as little as 7 or 8 feet, while in others, especially near the coast where the level has been raised by warping, it is as much as 15 feet above datum. High spring tides rise to a level of 16 feet above datum; hence the whole of the Marsh would be covered by water or "drowned" at such times, were it not for the Sand hills which border the coast and protect the land inside. Occasionally during great storms the sea has made a breach through this barrier and has flooded portions of the cultivated land.

The so-called submerged forest, which is seen at low spring tides along part of the coast, I believe to be only the shore outcrop of a subterranean peat bed (see p. 109).

In the following account of the observations made in these areas I shall commence along the southern border of the sheet and work northwards through the Marsh.

Local Details.

The area lying east of Stickford and south of the Catchwater Drain is a low lying tract, the surface of which is only about 4 or 5 feet above ordnance datum. As late as the end of last century this tract was a wilderness of fen, meres, and morasses. Gough, in his edition of Camden's Britannia (1789), gives the following description of the East Fen :—

"It is quite in a state of nature, and exhibits a specimen of what the country was before the introduction of draining. It is a vast tract of morass, intermixed with numbers of lakes, from half a mile to two or three miles in circuit, communicating with each other by narrow reedy straits. They are very shallow, none above 4 or 5 feet deep, but abound with pike, perch, ruffs, bream, tench, dace, eels, &c."

All these meres and ponds were known by different names; a map showing their position is given by Sir W. Dugdale,* and is copied in Plate III. of Skertchly's Geology of the Fenland,† but their sites are now entirely obliterated, and the surface presents a rich black peaty soil from two to 3 feet thick.

In the other and higher parts of East Fen, the surface consists of sandy warp or clay with one or more peat layers below; thus Mr. Skertchly notes at Fodder Dyke in East Fen (Sheet 69) the peat is thin and rests either on silicious sand of variable thickness (never more than 3 feet) or more usually on Boulder Clay. Three-quarters of a mile down the Drove the peat is underlaid by sandy warp (silt), and on the Hobhole drain the succession is first peat at the surface, then the sandy warp, and silty clay below, with marine shells.

At Lade Bank engine there is the following section:—

	feet.
Warp - - - - - - -	6
Peat - - - - - - -	1
Clay - - - - - - -	3
Peat - - - - - - -	0½
Clay - - - - - - -	—

Further on the two layers of peat unite, the clay between them thinning out (extracted from Mr. Skertchly's note book).

For information as to the draining of these fens, which was not commenced till the year 1801, the reader may refer to Mr. Skertchly's Memoir above quoted. The first operations were only temporarily successful, and the drainage gradually became defective until in 1866, owing to the heavy rainfall; the fens in question had reverted almost to their pristine condition, and the level was described "as having the appearance of one extensive lake, the course of the drains being undistinguishable from the submerged lands."‡ But since the erection of the engines at Lade Bank, and the improvement of the Witham outfall, the drainage has been quite satisfactory and will probably remain so.

The clay land sets in on the west side of the Great Northern Railway, and extends eastward by Thorpe and Wainfleet to the sea-coast. On the north it runs up between the mounds and ridges of Boulder Clay which lie between Firsby and Burgh, occupying what were evidently once inlets

* History of Embanking and Draining, 1722.
† Mem. Geol. Survey, p. 40.
‡ Mr. H. Wheeler; quoted in Skertchly's Geology of the Fenland, p. 48.

of the sea. The Boulder Clay passes southward beneath this marine alluvium, and everywhere forms the floor upon which the newer clays rest at depths of from 5 to 20 feet.

About half a mile S.E. of Irby Church, on the road leading to Thorpe, Boulder Clay may be seen passing beneath brown silty clay in the side of the dyke, and southward near the bend in the road a layer of peat is visible at the dyke bottom, overlain by about 5 feet of clean clay.

At the brickyard, one mile S.S.E. of Irby, the following beds are exposed when excavations are made:—

	feet.
Brown clay	4 to 5
Turf, with tree trunks	1½ ,, 2
Blue buttery clay	3 ,, 8
Sand in places	0½
Greyish-blue Boulder Clay, seen for	6

The thickness of the buttery clay varies very much, because it rests on an uneven surface of the Boulder Clay. The latter is not bottomed at the pit, but must be from 10 to 12 feet thick, for it was pierced by a well at the house on the east side of the road, water being found in sand at a depth of about 20 feet.

The peat bed may be traced at intervals along the road from this point to Thorpe Culvert Station, its depth from the surface being about 4 or 5 feet, and it is seen in all the brickyards near Thorpe.

The brickyard W. of Thorpe Culvert Station, belonging to Mr. Worth, exhibits the following section:—

	feet.
Stiff upper brown clay	6
Turf, with trees, nuts, &c.	1½
Clean brown silty clay	3
Darker purple clay, with *Scrobicularia piperata*	6
Turf, with trees	0½
Red clay, with stones	6 +
	24 +

The foreman stated that the bottom stony clay differed from that at the Irby brickyard in having very few chalk stones, the other being a marly clay, full of chalk. They had dug 2 yards into the stony clay, but had never penetrated it. The clay which is in contact with the turf, both above and below, is discoloured and stained grey. The lower purplish clay contains streaks and nests of bright blue Vivianite (phosphate of iron).

At Mr. Scarborough's brickyard, two furlongs south of the above, I found the following section in 1881:—

	feet.
Brown clay	5
Turf, with tree trunks	2 to 3
Grey and brown silt, with roots	1
Brown argillaceous silt, passing down into purple-blue clay full of *Scrobicularia piperata*	9 to 10
Turf, with roots and trees, from a few inches to	1

The workmen stated that this lower turf bed rests on a "marly clay" containing chalk stones, which they had dug into for 30 feet, but had not pierced. Many of the Scrobicularia were perfect, with united valves.

There is another brickyard, one mile east of the railway station, exposing:—

	feet.
Stiff brown clay	5
Turf, with trees	1
Blue buttery clay, with *Scrobicularia piperata*	6

The workmen stated that at the old pits near by, the buttery clay was 11 feet thick, and that below it they found a red clay, with stones, then a thin layer of turf, resting upon "marl" (*i.e.*, Boulder Clay).

Wainfleet stands on a bank of silt, the surface of which is 6 or 8 feet higher than the surrounding marsh; the railway cutting west of the railway station is 8 feet deep in the centre, and passes through loose light brown sandy silt.

About a mile and a half from Wainfleet, where Croft Drain crosses the road to Skegness, there is a knoll of sandy gravel, and this leads on to a long bank of sand and shingle which reaches to within half a mile of Skegness Station. It is known by the name of Croft Bank and the Roman road appears to have been carried along it. The sandy gravel or shingle of which it is composed was seen (1877) to pass eastward under the silty-clay of the marsh in an excavation half a mile N.N.W. of Cow Bank Station; 3 or 4 feet of gravelly and sandy material was here exposed, coming to the surface near the road, and containing the following shells, many of them being very abundant:—

Ostrea edulis.	Fusus antiquus.
Cardium edule.	Purpura lapillus.
Tellina solidula.	Littorina littorea.
Solen siliqua?	Murex erinaceus.
	Trochus cinerarius.

A larger pit at the corner of the road leading to Cow Bank Station showed about 5 feet of sand and sandy gravel, with many fragments of the same shells. Here bones of *Cervus capreolus* and of a sheep or goat were found in 1878, and are now in Mr. Jabez Good's Museum at Burgh.

At the brickyard half a mile N.N.E. of Croft Church a section 10 feet deep was seen in a new excavation (1877), the rest of the following details being obtained from the foreman:—

	feet.
Brown sandy clay	7
Peat, with wood, &c.	1
Soft grey buttery clay	12
Black sandy silt	0¼
Yellowish marly clay, with chalk pebbles	4 +
	24 +

Water is thrown out at the base of the sandy clay, through the peaty layer, by the sticky impervious clay below. The peat bed contained wood and stems and broad leaves like those of the seaweed *Laminaria;* bones were said to occur in it occasionally. There seemed to be much iron in the clays and a salt efflorescence.

Here it is the buttery clay, which is chiefly worked for making red tiles and bricks; the marly clay at the bottom was said to make good white bricks, when ground up.

At the Burgh brickyard, on the road three-quarters of a mile W. of the Church, the following section was obtained, partly from observation and partly from information given by the foreman of the works with reference to the lower beds:—

	feet.
Brown clay, mottled with bluish-grey, and becoming silty and laminated towards the base	6
Bed of peat, with bark and trees	2
Soft clean bluish-grey "buttery" clay	6 to 7
Greyish-white clay, with chalk stones	5+
	19+

The uppermost clay is the most serviceable, and is used for making the best tiles and drain pipes. A considerable surface of the peat bed was exposed in 1877; it contained logs of oak, soft wood like sallow or birch, and birch or alder bark. The buttery clay is used to mix with the upper clay for brick making, and the bottom (marly) clay is sometimes dug out and crushed; it makes whitish bricks, the others burning red. Thickness of marly clay unknown, but proved in boring five furlongs north of this (see Appendix B. p. 151).

In the brickyard near and N.E. of Skegness Station the following section was observed close to the road :—

	feet.
Stiff mottled brown clay	5 to 6
Turfy layer mixed with clay	1
Bluish-grey clay	7 to 8

About 200 yards N. of the road a new excavation showed 6 feet of the upper brown clay, overlying, without the intervention of any peaty layer, a soft laminated silty clay, the upper portion of which was brown and the lower part grey in colour. In the same field, however, but more to the W., turf again occurs between the clays, consisting of black peaty knots, roots, and stems in a matrix of brown clay; sulphide of iron is developed in places, and I found a single shell of Cardium edule in this layer. These shells were common in the upper clay. The foreman informed me that 8 yards nearer the road he had sunk to a depth of 18 feet without piercing the laminated silty clay; this is only used for making the commoner bricks, the best bricks and tiles being made from the upper clay.

The land between the present sand dunes and the Roman bank, which runs from Skegness to the shore opposite Ingoldmells, is several feet higher than the surface on the west side of this bank, having probably been raised by a process of warping. Just inside an angle of this bank, half a mile S.E. of Winthorpe, there is a brickyard showing :—

	feet.
Brown silty clay or "warp"	5
Black silty clay, or mud	3

The lower clay passed laterally into yellowish clayey silt, and the foreman supposed the above to be on the line of an old muddy creek or "low" (1877).

No bed of peat was met with in this brickyard, the bottom of the excavation being probably above the level of the peaty layer seen elsewhere.

At Skegness and Winthorpe the depth of the Post-glacial Marsh Clays is about 30 feet, but westward the Boulder Clay floor rises nearer to the surface, and about 2½ miles west of Winthorpe it is only 10 feet from the surface (see Appendix p. 151). At Orby Grove, north of Burgh Common, it is in some places only 4 feet below the soil, while Orby Holmes and Habertoft stand on islands of Boulder Clay, surrounded by level marsh.

The inlet south of Sloothby is occupied by clay, and Mr. Brooks of Hasthorpe informed me that the bricks used in the construction of his house were obtained from a spot about half a mile to the east, where there is clean bluish brick clay for a depth of 20 feet, with sand beneath.

Farther eastward, near the houses called Wyche on the map, the depth of marsh clay is not so great, and it frequently contains the trunks of large trees; these probably rest on a thin layer of turf at its base, for there is an old brickyard near Brothercrofts' gout, which was formerly worked by Mr. Spalding of Hogsthorpe, who described the section as follows :—

	feet.
Unctuous brown clay, bluish below, and containing large trunks of oak, and cockle shells in abundance near the bottom	7
Thin layer of turf on which the trees rested	0½
Stiff marly clay with stones, not pierced	?

In the neighbourhood of Chapel the Marl or Boulder Clay is seldom more than 12 feet from the surface, and it crops out on the shore at several places near low-water mark. Between tide marks the soft sticky buttery clay is often exposed by the shifting of the sands, and, as these exposures generally form hollows, they are locally known as "*mud lows.*"

At Chapel Tunnel a new cut was made for the drain in 1879, and the following section was exposed about 50 yards west of the bridge:—

	feet.
Tough brown clay, containing *Ostrea edulis* and *Scrobicularia piperata*, and passing down into blackish clay, mixed with peaty matter	5
Yellow sandy silt	3
Brown Boulder Clay, with chalk pebbles	2+

The silt varies in thickness, and fills up hollows in the surface of the underlying Boulder Clay, which is very uneven, and rises to the top of the ground both to the west and north-west of the spot above-mentioned. A stiff reddish silt is generally banked up round these hummocks of Boulder Clay, which rise like islands out of the dead level of the surrounding Marshland. The conformation of the ground here is illustrated in the section through Hogsthorpe and Chapel in the Plate at the end of the volume. North of Dudic Bank the depth of marsh clay and silt is said to be about 30 feet.

The brickyard half a mile N.N.E. of Hogsthorpe (in the occupation of Mr. Spalding, 1879), exposes a variable thickness of clean brown clay, mottled with dark blue, lying on an uneven surface of Boulder Clay, which rises to the surface both east and north of the pits. At the more northerly pit the brown clay rests on a bed of hard greyish silt full, of stones, and thickness from 0 to 9 feet, and in the field to the S.W. it is said to be 17 feet deep. It contains a thin seam of turf about 5 feet from the surface, and near the bottom oysters and occasionally bones are found; a skull of *Bos primigenius* obtained from this pit is in the possession of Dr. Thimbleby of Spilsby; an ilium of an animal about the size of a deer and a specimen of *Ostrea edulis* were given me by Mr. Spalding.

The clay here is of excellent quality for making bricks and tiles; those made are red in colour and of a very close fine texture. Westward inlets of the marsh run up to Cumberworth and Willoughby. In these the surface soil is a stiff brown clay, like that at Hogsthorpe, but local layers of turf frequently occur in or below this clay; for instance in the low ground five or six furlongs S.W. of Helsey a bed of turf nearly a foot thick is exposed in some of the dykes. Again to the west and north of Butterbump, near Willoughby, the surface soil is black and peaty, with a yellowish-brown clay beneath, and those who have drained the land state that at a depth of 3 or 4 feet there is a bed of turf underlain by blue brick-clay.

Between Hogsthorpe and Anderby the flatness of the Marshland is broken by island-like hillocks of Boulder Clay, between which the marsh-beds are generally of a silty character. Langham Row stands on a bank of silt which is slightly elevated above the rest of the plain, like that at Wainfleet, and S.E. of Autoft Row* reddish sandy silt is exposed in the ditches.

Just north of Anderby Creek there is a brickyard showing two feet of yellowish sandy silt, with purplish-brown clay below, mottled with dark-blue, and containing *Ostrea edulis* and other shells (about 10 feet seen). The proprietor stated that a well was dug to let off the water which accumulated in the pit; this passed through 20 feet of the brown clay, below which there was a foot of black turf, with sand underneath (for well section at Mr. Robinson's a quarter of a mile S.W. of this see p. 150).

By Huttoft the Marshland is reduced to its narrowest dimensions, its width here being less than a mile and a half. Northward by Sutton,

* This name is wrongly spelt Authorpe on the Ordnance map. I found the inhabitants spoke of it as Autoft Row.

Trusthorpe, and Mablethorpe it has an average width of two miles, and sends inlets between the ridges and mounds of Boulder Clay to the westward. The relative position of the Marsh beds in this neighbourhood is illustrated by sections 2 and 3 in the plate at the end of the volume.

It is along this portion of the coast that the so-called "forest-bed" is best exposed at low water of spring tides. The following is Mr. De Serra's account of this bed as seen by himself and Sir Joseph Banks at Sutton in 1799:—*

"The sorts of wood which are still distinguishable are birch, fir, and oak. The bark of the trees and roots appeared generally as fresh as when they were growing, in that of the birches particularly, of which a great quantity was found; even the thin silvery membranes of the outer skin were discernible. The timber of all kinds, on the contrary, was decomposed and soft, in the greatest part of the trees; in some, however, it was firm, especially in the knots. . . . . In general the trunks, branches, and roots of the decayed trees were considerably flattened. . . . . The soil to which the trees are affixed, and in which they grew, is a soft greasy clay, but for many inches above its surface the soil is entirely composed of rotten leaves, scarcely distinguishable to the eye, many of which may be separated by putting the soil in water, and dexterously and patiently using a spatula or a blunt knife. By this method I obtained some perfect leaves of *Ilex aquifolium*, which are now in the herbarium of Sir Joseph Banks; and some other leaves which, though less perfect, seem to belong to some species of willow. In this stratum of rotten leaves we could also distinguish several roots of *Arundo phragmites*.

"These islets (into which the forest bed is broken up) extend at least 12 miles in length and about a mile in breadth. The water without them towards the sea generally deepens suddenly so as to form a steep bank. The channels between them, when the islets are dry, in the lowest ebbs of the year, are from 4 to 12 feet deep; their bottoms are clay and sand, and their direction is generally from east to west." A well dug at Sutton by Joshua Searby shows that a moor of the same nature is found underground in that part of the country at the depth of 16 feet; consequently very nearly on the same level with that which constitutes the islets. The disposition of the strata was found to be as follows (see Appendix B, p. 171).

"This moor extends over all the Lincolnshire Fenland, and may be traced as far as Peterborough on the south, and Grimsby on the north, abounding with trunks and roots of trees. Little doubt can be entertained of the moory islets of Sutton being a part of this extensive subterraneous stratum, which by some in-road of the sea has been there stripped of its covering of soil. The identity of the levels; that of the species of trees, and above all the flattened shape of the trunks, branches, and roots found in the islets, which can only be accounted for by the heavy pressure of a superinduced stratum, are sufficient reasons for this opinion."

FIG. 20.

Section through the beds seen at low-water near Mablethorpe.

a Forest-bed. *b* Clay. *c* Sand.

In this opinion I quite concur, and I had in fact arrived at the same conclusion from an independent consideration of the facts before reading the paper from which the above is extracted. I examined the "forest-bed" at Mablethorpe during the spring tides of July 1881, when it was well exposed at dead low water. I found it cropping out at the bottom of a gentle slope, composed partly of clay and partly of sand lying on the clay, under which the turf or "forest-bed" appeared to pass, as shown in Fig. 20.

* Phil. Trans., vol. 89, p. 145.

The clay in contact with the peat is of a greenish-grey colour, evidently discoloured by the influence of decaying organic matter, as seen in the brickyard near Thorpe Culvert station, while in the clay holes above the clay is of the usual brown colour; but where I was able to dig through the peat I found a similar greenish silty clay beneath.

The peat bed seem to be from a foot to a foot and a half thick; it consists of a black matted mass of roots, twigs, leaves, and pieces of bark, in which numerous stumps of trees are standing up in position of growth and apparently rooted in the peat and underlying clay; some of them are large and look like stumps of oak, others are small and resemble stumps of birch or fir, while birch bark is common in the peat itself. This array of tree stumps extended southward along the shore to Sutton and Huttoft Bank, but was not exposed very far to the north of Mablethorpe.

At Trusthorpe, opposite the Church and close under the sand hills, an excavation made in 1881 showed the following beds:—

	feet.
Brown clay	1
Peat	0½
Silt	1

proving the existence of a second bed of peat at a higher level, which, however, seems to have a very limited extension, as it is not seen in any of the brickyards inland. Neither do the open sections in these yards go deep enough to reach the level of the low water forest bed, which must lie about 16 or 17 feet below the surface of the land, if it extends westward beneath the Marsh.

Mr. W. H. Penning, who surveyed the neighbourhood of Sutton and Mablethorpe, has the following notes on the brickyard one mile west of Sutton Church:—

"In the pit are seen—

Brown clay	5 or 6 feet.
Laminated sandy clay	5 ,,

"The pit is full of water (May, 1880), but is said to be 25 or 30 feet deep in black clay (? silt), 'moor' (forest bed ?), clay with trees, and clay with round shells like cockles; there is also clay with white specks (? Boulder Clay). Some tea-green clay turned out with yellow vegetable markings. The 'moor' is said to be just like what is seen at low water on the beach."

I visited the brickyard N.E. of Mablethorpe in 1881 and saw brownish clay (about 5 feet) with dark brown silty clay below (8 feet), and the owner informed me that in boring water a layer of peat (2 feet thick), was found about 20 feet from the surface. In the well sinker's account (see Appendix B, p. 163) the position of the turf bed is different, and perhaps there are two beds.

At the brickyard, one mile N.E. of Maltby Church, Mr. Penning found—

	feet.
Brown clay, weathering tea-green in places	2 to 3
White silt, irregular and discontinuous	—
Black clay, seen for	3 or 4

The workmen reported marl with stones (Boulder Clay) as occurring below, and the depth of the pit as 20 feet; there had been heavy rains and the pit was then full of water (May, 1880).

Mr. Penning also observed the following section in a ditch by "Earl's Bridge," on the road to Mablethorpe:—

	feet.
Brown clay (Warp)	3
Black clay and light silt	0½
Brown clay with stones (Boulder Clay)	2+

The next exposure is in a brickyard half a mile E.N.E. of East Theddlethorpe Church, where they dig through brown sand to the marsh clay below, the section here in 1881 being as follows :—

	feet.
Blown sand, obliquely and irregularly stratified with layers of pebbles of coal, jet and shells	10 to 12
Dark brown clay, seen for	4

Mr. Egglison (the owner) informed me that he had dug into clean brown buttery clay for about 25 feet further and had found large bones, said to be those of an elephant's leg, at a depth of 22 feet.

At Saltfleetby there is a brickyard about three-quarters of a mile S.W. of St. Peter's Church, and here the following section was obtained, partly by observation and partly by information from the proprietor (Mr. John Cannon) :—

	feet.
Soil	1
Reddish-brown clay	4
Blackish or dark clay, with shells	5
Turf, with roots and oak trees	0½
Sandy clay, with flint stones	2
Marl full of "whites," dug for	18

(For beds below this, see Appendix B., p. 167.)

No other exposures were seen between this and North Somercotes, where there is a brickyard half mile south of the Church ; this shows about 8 feet of reddish-brown clay containing *Scrobicularia piperata* and *Cardium edule*. The foreman said he had sunk deeper and found the "marl" (Boulder Clay) at a depth of about 15 feet from the surface. As the usual depth hereabouts is from 25 to 40 feet (see Appendix B., p. 170), this must be on the top of a mound of Boulder Clay.

In Conisholme Fen, near a farm nine furlongs S.W. of the Church, there is a layer of brown laminated sandy silt exposed in the dyke sides, beneath one or two feet of stiff blue clay.

In Grainthorpe Fen, a mile and a half W.N.W. of Conisholme, there is a brickyard showing the following beds :—

	feet.
Reddish clay	5
Bluish clay	6
Layer of turf, with trees	0½ to 1½
Stony clay Marl (Boulder Clay) } According to the foreman.	

§ 3. Blown Sand.

The whole coast line of East Lincolnshire, from Gibraltar Point south-east of Wainfleet to Donna Nook north of Saltfleet, is bordered by a narrow range of sand hills, the sand composing them being blown off the foreshore outside. This strip of Blown Sand is widest near the southern and northern edges of the map (sheet 84), being about a quarter of a mile (440 yards) wide at these points, it is also about the same width near Saltfleetby, but elsewhere it is very narrow, and in some place not more than 50 or 60 yards broad. The sand is piled up into mounds and hummocks, and is held together by a growth of "mat grass" or "marram," (*Arundo arenaria*) with which *Hordeum maritimum* (coast barley) and *Triticum junceum* (wild wheat) are frequently associated ; the Sea Buckthorn (*Hippophea rhamnoides*) and

the Blue Bramble (*Rubus cæsius*) are also abundant, and their roots assist in holding the sand together. In height the sand hills vary from 20 to 40 feet above the level of the land inside, which they protect from the inroads of the sea.

Opposite Ingoldmells a portion of the sand hills about 500 yards long was swept away during a storm and high tide in 1877, the land lying between the shore and the Roman bank being inundated, and it is possible that the continuation of the Roman bank has been carried away by the encroachments of the sea outside Chapel. Near Sutton and Mablethorpe also the hills have often to be artificially strengthened, but northward by Theddlethorpe and Saltfleetby they are increasing.

Near Saltfleet a considerable tract of land has been reclaimed by inducing the formation of a new line of sand-hills (see map). This was done in 1856 by fixing a line of fascines to arrest the sand which blows off the shore during easterly winds; when once started the sand continues to accumulate, and there is now a good bank covered with marram grass running from the outfall at Saltfleet to Donna Nook, in sheet 85, with a cultivated space, from 400 to 800 yards in width, between it and the old line of sand-hills.

North Somercotes stands on an old beach which passes eastward under blown sand. There are numerous pits in and around the village, the depth of the shingle varying much. In one, half a mile N.E. of the Church, I saw shingle with cockles and oyster-shells, overlaid by 3 feet of blown sand. In the village there is stratified sand, with layers of shingle for 6 feet, and sand below, according to the workmen.

CHAPTER IX.

THE HILLS AND VALLEYS OF THE WOLDS.

AN EXPLANATION OF THE PHYSICAL FEATURES OF EAST LINCOLNSHIRE.

The principal physical features of the district which lies within the limits of Sheet 84 were indicated in Chapter I., and their relation to the general geological structure of the country was explained. In many parts of England it would be difficult to add much to this explanation beyond stating that the valleys of the district had been gradually carved out of its original surface by the erosive action of rain, springs, and rivers: it is not always possible to arrive at any definite conclusions with regard to the relative age of the valleys which intersect any tract of country or to construct any historical account of the conditions under which its present system of drainage has come into existence.

The survey of the Lincolnshire Wolds has, however, furnished me with facts which have made it possible to explain the origin of many of their minor features and to indicate the probable changes which have taken place during what may be called the evolution of the system of valleys by which the natural drainage of the district is effected. The present Chapter is, therefore, a sketch of the gradual development of the distinctive scenery of the Lincolnshire Wolds, and will, I hope, prove interesting to all who are acquainted with any part of that district. The valleys of these Wolds have a beauty of their own which is appreciated by many of their inhabitants, but surprises those who are strangers to this part of England, and labour under the popular error that the county consists entirely of marsh and fenland.

Modern Processes of Erosion.—There is no part of England where the processes of valley erosion can be studied better than in the Lincolnshire Wolds, or where their origin can be more clearly traced to the action of rain and springs. The part taken by rain in the excavation of valleys is well known to every student of geology, and the manner in which rain is assisted by the action of springs has often been pointed out. Excellent examples of this combined action are to be found in the valleys of the small tributaries which feed the larger streams of the district.

If the reader can ascend the valley of one of the little becks which are the feeders of the River Steeping, he will find that it commences in a shallow depression on the clay land which forms the watershed; retracing his steps he will observe that this gradually becomes a well-marked channel, which, however, is not

permanently occupied by running water until it approaches the base of the Spilsby sandstone, where strong springs always break out. The upper valley is only a rain channel, and water only runs down it after unusually heavy rains; the course of this dry valley was much longer originally, but has been shortened by the recession of the spring-heads to their present position. Whether the course of the rain channel determined the position of the springs, or the position of the springs affected the course of the rain runnels it is difficult to say; but once fixed it is clear that the channel would be gradually deepened and the spring-heads would be gradually pushed farther and farther back. This process is still in operation, for in wet weather the ground near the springs is a mass of soft sliding slush, which slowly slips and founders down towards the rivulet at the bottom of the valley. After heavy rains these rivulets are turbid with mud and sand, a proof of the detrition which is in progress; but in dry weather the streams are as clear as crystal, a proof that no such work is then going on.

It is only in these tributary valleys that the work of erosion is still in action; for the alluvium which occupies the whole length of the main valley of the Steeping River testifies that this has long since been reduced to the base level of erosion, and that deposition, not erosion, is there taking place.

Similar operations may be witnessed in some of the valleys which intersect the Chalk Wolds. The most remarkable and interesting of these is that of the stream which runs from Oxcombe and Farforth to join the Calceby Beck. West and north-west of Worlaby there is a broad dip slope of chalk, the eastern border of which is trenched by no less than five deep valleys, ending in rounded combes, from the sides of which strong springs are always gushing forth. Above and beyond the springs there is a dry chalk valley, which is only a watercourse in times of heavy rain. By the light of these facts one can easily look back to the time as not far distant, geologically speaking, when the most easterly spring was near the hamlet of Farforth, and the valleys to the west and south of that place were depressions in the chalk only, without springs, and not therefore permanent watercourses. The deepening of these dry chalk valleys and their conversion into permanent watercourses has been caused by the recession of the spring-heads from Farforth to the points which they now occupy. This recession has proceeded so far that in several places the base of the Chalk is cut back to within a short distance of the main line of escarpment, leaving only a narrow ridge as a watershed between the two slopes. The view from the summit of this ridge is exceedingly unique and picturesque, on the one hand over the broad valley which lies at the foot of the escarpment and on the other hand into the deep combes which have been excavated by the recession of the springs. It is probable that this recession has nearly reached its ultimate extent, for little water is now thrown out at the extremities of the valleys

except after very heavy rains. It is also clear that the stream into which the waters are gathered is doing little erosive work, for a narrow strip of alluvium is traceable nearly all the way from Oxcombe to Ketsby Mill. Between Ketsby and Calceby it is probable that the stream is eroding its bed, but the Calceby Beck into which it falls is bordered by alluvium, and is not therefore increasing the depth of its valley.

It is quite possible that the accumulation of alluvium in the valleys of the Steeping and Calceby Becks to such a great distance from the points where they debouch on to the level of the Fen and Marsh respectively may be due to a comparatively recent depression of the land, the same depression which submerged the buried forests and allowed the sea to encroach so far upon the great tract of Boulder Clay which once occupied the site of the Wash.

Before this depression and when the land stood at a higher level, if only by 40 or 50 feet, erosion must have been more rapid and was not confined to the uppermost tributaries of these valleys, but must have been in progress for a much greater distance from their sources than is now the case. I have elsewhere* pointed out that every such elevation or depression of land must be accompanied by a change in the rapidity of the subaerial processes of erosion.

Relative Age of the Calceby and Steeping Valleys.—A study of the two valley systems which are connected respectively with the Calceby Beck and the Steeping River suggests some interesting conclusions which I have already communicated to the Geological Society of London, and which I am permitted to reproduce here.†

The valley of the Steeping is parallel to the strike of the rock-formations, and the valley of the Calceby Beck is at right angles to the strike, cutting completely through the Chalk hills. The latter is therefore what Mr. Jukes termed a transverse valley, and the former is a longitudinal one, but their relation to one another is not that which ordinarily exists between transverse and longitudinal valleys: the stream in the longitudinal valley is not a tributary of the other, but flows away from it, and the upper part of its valley lies at a lower level than the adjoining part of the transverse valley.

Both streams now rise in the neighbourhood of Tetford: the Ormsby Beck which is the principal upper tributary of the Calceby stream, rises in Holster Dale, north-west of Tetford, while other smaller tributaries originate from the springs near Cloven Hill, Brinkhill, and Driby Grange. These unite into a fair-sized brook N.W. of Driby, and flow north-eastward by Calceby and South Thoresby. Near Calceby this also receives the long tributary above mentioned from Oxcombe and Farforth,

* Handbook of Physical Geology, p. 111.
† Quart. Journ. Geol. Soc., vol. xxx., p. 599.

which runs in a longitudinal valley. To this and another tributary which comes in opposite South Thoresby I shall revert in the sequel.

If we now turn to trace the course of the Steeping River, we find that its head waters flow from the hills near Belchford, and form a brook which runs easterly through Tetford, where it is joined by a smaller beck from Tetford Wood. The valley of the brook which runs eastward is continuous with the Ormsby Valley, but the Tetford Brook, instead of pursuing what appears to be its natural course, turns southward at right angles to this course, and passing through a narrow gorge in the Neocomian Sandstone issues into the broad valley of the Steeping at Somersby. Another tributary is formed by the becks which rise on the Neocomian Hills between Fulletby and Ashby Puerorum. A third rises on the hills near Greetham, and joins the main stream near Stockworth Mill, where a fourth tributary comes in from the north. This last runs from Warden Hill, and looks as if it had once flowed into the Brinkhill Valley and so to the Calceby Beck, though now it turns southward, like the Tetford Brook, and runs through Harrington Carr into the Steeping.

The Brinkhill Valley, which is the direct continuation of the transverse valley of the Calceby Beck, has a truncated appearance, and it is difficult to account for the existence of such a broad gap as that between the spurs of Cloven Hill and Harrington Hill, unless it was originally formed by brooks which rose at a considerable distance to the westward. Now, were it not for the interposition of the longitudinal valley of the Steeping, it is clear that the brooks rising on the Neocomian Hills near Greetham would naturally drain into this Brinkhill Valley and become tributaries of the Calceby Beck.

The peculiar relations therefore of the Calceby and Steeping Valleys suggest that the former has been excavated by streams flowing eastward from the Neocomian Hills before the upper part of the Steeping Valley had its present extension; and that these streams have been intercepted and diverted by the subsequent elongation of the Steeping Valley.

This view of the relative ages of the two valleys receives strong confirmation from the disposition of the later Glacial deposits and the relative extent to which the two valleys are occupied by these beds (see Map, Fig. 21).

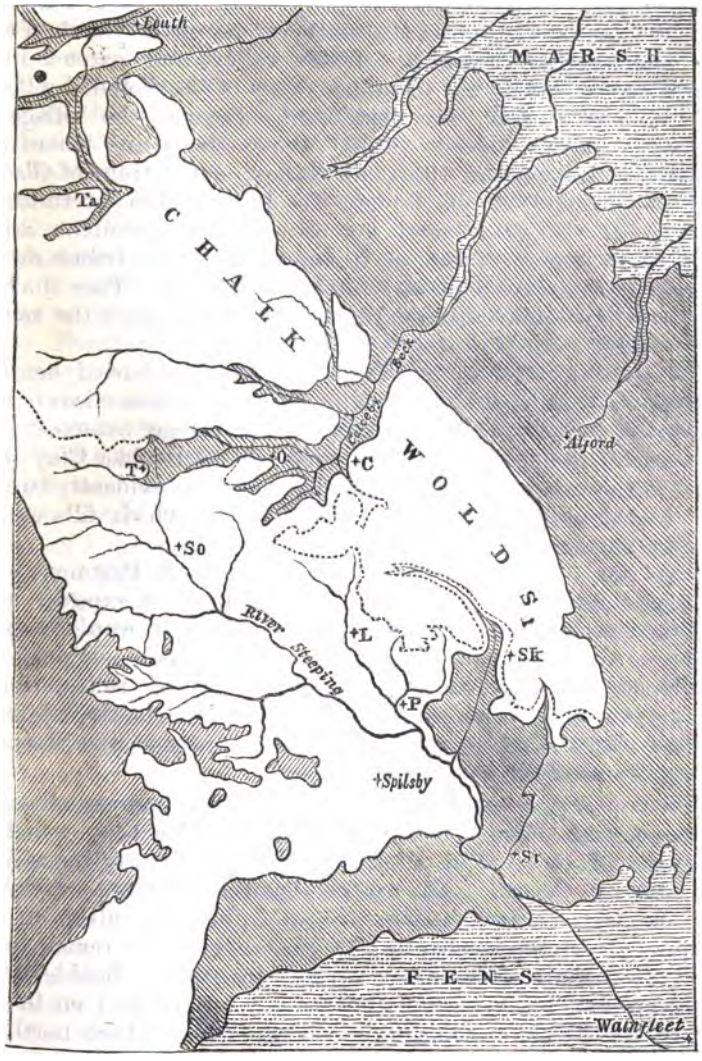
The valley of the Calceby Beck is occupied from end to end by accumulations of Glacial Clay and Gravel, and the present beck has nowhere been able to cut its channel down to the bed of the ancient river by which the valley was originally formed. At South Thoresby the rock-bed of the valley is probably some 40 feet below the surface of the present stream, and an inspection of the map will show that masses of Glacial Gravel stretch up the Ormsby and Brinkhill Valleys beyond the head waters of the becks which now flow through them. It is clear therefore that

FIG. 21.

*Sketch Map of part of East Lincolnshire.**

Scale 3½ miles to 1 inch.

The dotted line indicates the escarpment of the Chalk; the diagonal shading represents Boulder Clay.



St	=	Great Steeping.	C	=	Calceby.
P	=	Partney.	So	=	Somersby.
Sk	=	Skendleby.	T	=	Tetford.
L	=	Langton.	Ta	=	Tathwell.

* This map is reproduced from the Quart. Journ. Geol. Soc., vol. xxxix., p. 600, by permission of the Council.

the whole of this valley was formed before the deposition of these Glacial beds. We cannot say for certain that it was a pre-glacial valley, because these deposits belong to the newer part of the Glacial Series, and there is no evidence to prove that it was in existence before the formation of the older (chalky) Boulder Clay.

If we now turn to the Steeping Valley we find that the Boulder Clays sweep round the southern end of the Chalk Wolds into the bay-like entrance of this valley, and extend in a narrow tongue far up the tributary valley of the Skendleby Beck, which comes in from the northward. Beyond the village of Partney, however, about a mile above the point where the Skendleby Beck enters the main valley, not a trace of Glacial Clay or Gravel is to be found; the Boulder Clay terminates abruptly at this point, and not the smallest remnant exists further up the main valley or in any of its other tributaries to indicate that it ever had any further extension. This limit is only about two miles distant from a line drawn across the mouth of the valley from Halton to Candlesby.

The ancient outlet of the Skendleby Beck is buried beneath the Glacial deposits, and is doubtless at a much lower level than the present bed of the Steeping River. This stream has excavated a channel through the western edge of the Boulder Clay, and down to the underlying Kimeridge Clay, being evidently turned aside by the great mass of the Boulder Clay which fills up the bay-like entrance to the valley.

From the termination of the Boulder Clay near Partney to the furthest point at which the Kimeridge Clay is exposed, viz., near Salmonby, is a distance of seven miles; it would appear therefore that the Spilsby Sandstone has been stripped off the Kimeridge Clay throughout the whole of this distance during the time which has elapsed since the formation of these Boulder Clays; that is to say, the greater part of the Steeping Valley is entirely of Post-glacial origin.

The mapping of the district by Mr. Strahan and myself leads us to conclude that before the oldest Boulder Clay was laid down the Chalk escarpment occupied a more westerly position, and that a broad platform of the Tealby Clay stretched over the tract which is now trenched by the valley of the Steeping; outlying remnants of this platform still remain near Hagworthingham. Upon this surface the chalky Boulder Clay was deposited, and was probably banked up to and on to the edge of the chalk escarpment, as is the case further north in Sheet 83.

Whether the transverse valley of the Calceby Beck was in existence at this period is very doubtful; I am inclined to think it was not, though it is quite clear that it had been formed before the period of the later Boulder Clays. If, as Mr. Searles Wood supposes, there was a long interval between these two Glacial periods, and if this interval was a period of elevation, we

may reasonably suppose that the Wold Valley system originated during this time. The clay-capped Neocomian Hills would form a watershed, whence some brooks would run to the west and south-west, others to the north-east, down the dip-slope of the Chalk, and some of the latter concentrating near Driby must have excavated the transverse valley of Calceby and Thoresby. Lastly, a few smaller becks, those of Bolingbroke, Skendleby, and Scremby, drained the southern border of the Wold Hills.

I have assumed that the Steeping River had no existence at this period, but the extension of the newer Boulder Clay to Partney suggests that some small tributary of the Skendleby Beck came in from that direction, running at a much higher level than the Steeping and only cutting down to the Spilsby Sandstone in the vicinity of Partney. The junction of the older Boulder Clay and the Wold scarp would be a line of weakness, which would soon be widened by the action of rain and springs, and developed into a valley opening south-eastward. The Langton Beck may partially represent this line of drainage, since diverted into the subsequently formed valley of the Steeping; we may suppose the old Langton Beck, reinforced by the waters which now run into the Partney Beck, as joining the Skendleby stream near Ashby, and flowing south-east to the coast-line, wherever that was.

Such was probably the aspect of the valley system in this district before the period of the newer Boulder Clays. Then came, as I think, submergence, and the gradual accumulation of clays and gravels, not only in the pre-existent valleys, but over the whole surface of the Wolds up to heights of 400 feet. When at last this later Glacial episode had passed away, and detritive agencies began again to operate upon the land, the valleys above mentioned must have been nearly filled and choked with Glacial débris, but still remained as valleys or depressions along which the rain water could make its way; it is clear, however, that the land was not elevated to its former level, for these valleys have never been re-excavated to their original depth.

Let us now consider what would take place as the work of pluvial detrition went on; the Chalk hills would be gradually stripped of their mantle of Boulder Clay, and the rainfall would be absorbed by the Chalk, to be thrown out again in the form of springs. In the same manner the clay overlying the Spilsby Sandstone in the neighbourhood of Partney, Raithby, and Sausthorpe would be slowly removed, allowing larger areas of the sandstone to be exposed; more and more of the rainfall would be absorbed by this sandstone and thrown out from springs at its base, and thus a new element would be introduced among the forces of erosion. The spring-heads would recede in the manner already described, and this, combined with the continued action of rain, would cause the formation and rapid extension of a valley parallel to the strike of the sandstone. It could not but extend itself by recession to the north-west, because

the base of the sandstone has a decided slope to the south-east in the direction of the strike, causing all water to run in that direction.

There is nothing improbable, therefore, in the hypothesis that the valley of the Steeping gradually extended itself in this fashion until it encroached upon the tract drained by the upper tributaries of the Calceby Beck, and by reason of its cutting down to a lower base-line finally sapped and intercepted the waters of these tributaries, one after another.

The Tetford Beck was, of course, the last to be so intercepted, and from an examination of its case we may learn something of the manner in which the diversion was accomplished. It has already been mentioned that the valley of the Tetford Beck is really continuous with that of the Ormsby Beck, the intermediate portion being a broad plain which now forms part of the water-shed between the two valley systems; its centre is occupied by a broad strip of peat and alluvium, the western end of which drains into the Tetford Beck and the eastern end into the Ormsby Beck. This plain only exists because the ancient valley is choked up with glacial sand and gravel; and it is perfectly clear that if these accumulations were removed, the Tetford Brook would continue its easterly course into the Ormsby Brook, and so into the Calceby Valley. Indeed, the strip of alluvium indicates that this was the course of the brook up to a very recent period (geologically speaking), and that it was only deserted when an easier exit was found by the present channel.

The cause of this diversion now remains to be considered, but is not far to seek. The broad bridge of Neocomian Sandstone which lies to the south of Tetford is traversed by a deep and narrow trench, and through this the brook now escapes from the upper plain, and descends to the lower level of the Steeping Valley. It could not have done this until the spring-heads of the Steeping had receded to their present position.

It is most probable that this trench was originally formed by a small tributary of the Tetford Brook, draining the district to the southward and running northward to join it below Tetford. The drainage-basin of this tributary was gradually invaded and sapped by the recession of the spring-heads on its southern border, until it ceased to convey any water into the Tetford Valley and its northern portion would remain as a dry trench. As a combined action of rain and springs carried the head of the Steeping Valley further and further back, they worked down to a lower base-line than that of the Tetford Valley, and the Kimeridge Clay was gradually bared along the course of this dry trench. The strong springs which now issue from the base of the sandstone in this trench near Somersby show how the work was done. Eventually when the country had assumed its present configuration, and probably when the Tetford Brook happened to be in flood, the waters overflowed from the Tetford

Valley along this trench into that of the Steeping; and when this communication was once established it would be maintained, because being cut down to a lower base-line, the fall along the new channel is much greater than that along the old one.

If this was the manner in which the Tetford Brook became part of the Steeping River system, it is very likely that other streams may originally have drained into the Calceby Valley, and have been diverted in the same manner. The breadth of the Brinkhill Valley, its occupation by sand and gravel which is continuous with the drift of the Calceby Valley and its abrupt termination, are all facts suggestive of its once having had a longer extension and having received the waters of streams flowing from the westward.

Before the diversion of the Tetford Beck the extreme sources of the Steeping River would be at Salmonby; and before the diversion of the last-mentioned tributary they were probably near Stockworth Mill; and so we may work backward to the postulate with which we commenced, namely, that in early Post-glacial times, the sources of what subsequently became the Steeping River were not far from Partney.

Relative Age of the minor Valleys and Ravines.—The principles employed in the preceding study and comparison of the two larger valleys will aid us in ascertaining the relative age of the minor valleys and in explaining certain peculiar features which some of them exhibit. The presence of Glacial deposits in any valley may be taken as a proof that it was in existence before the formation of those deposits, and on the other hand the absence of any Glacial deposits in a valley may be held as raising a presumption of its Post-glacial origin.

Interesting cases occur in the course of some of the older valleys where the original watercourse has been so blocked up with Glacial deposits that when the ice had passed away and running water once more occupied the valley, the stream found it easier to cut a new channel for a certain distance than to remove the obstacles which filled up the old one. From such cases as these, where the cause of the new cuts is sufficiently obvious, I shall argue the explanation of other ravines, the existence of which would not otherwise be easy to account for, and which seem to have little connexion with any existing lines of drainage.

Beginning therefore at the south end of the Wolds, I will notice such valleys as present points of interest.

The Skendleby and Scremby Valleys have already been mentioned as in existence before the last Glacial episode. The Boulder Clay also fills up an ancient valley head opening eastward to the north of Gunby.

A small tongue of the same clay is thrust into the valley which crosses Shaddy's Walk, south of Claxby but the much longer valley which runs from Ulceby to Claxby, does not contain

any Glacial Clay and may therefore be of Post-glacial origin. Similarly the beautiful winding ravine known as Well Vale and the valleys near Haugh are unoccupied by drift, the boundary line of the Boulder Clay passing straight across their mouths.

It is not improbable, however, that these three valleys were marked out at an anterior period, when an extensive area of Chalk stretched eastward over the site of the marshes, before the invasion of the ice-laden sea which cut back the coast-line to the position indicated by the abrupt boundary of the Boulder Clay. The valleys at Claxby and Well may have been the upper tributaries of a valley system which drained a large area of chalk to the eastward, just as the water issuing from the springs at Well and Claxby now flows into the Willoughby High Drain, which runs eastward to Chapel.

The stream which excavated the Haugh Valley may have been a tributary of the river which flowed of old down the Calceby Valley, but if so it is curious that it should not have cut down to a lower level, for the mouth of the Haugh Valley at the Swallow Pits must be some 50 feet above the ancient bed of the Calceby Valley, near Belleau.

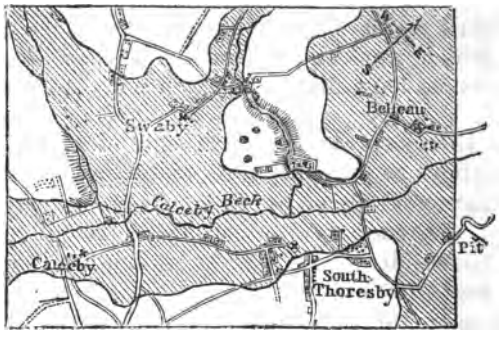
The neighbourhood of Swaby is interesting as furnishing a clear instance of Post-glacial erosion. The regular mounds of Glacial Clay and Gravel near this village have already been described (see p. 92); these accumulations completely block up the ancient course of the little stream which rises near Burwell, and is a tributary of the Calceby Beck. Above Swaby this stream is flowing southward, but in the middle of the village its course turns abruptly to the east, and enters a narrow ravine excavated out of the Chalk, which extends for a distance of about half a mile, and then opens into the main valley opposite the village of South Thoresby (see Fig. 22).

FIG. 22.

*Plan of the country near Swaby.**

Scale 1 inch to a mile.

The ground occupied by Drift is indicated by diagonal shading.



* This plan and the accompanying description are reproduced from my paper in Quart. Journ. Geol. Soc., vol. xl., p. 161, by permission of the Council.

The sudden change in the form of the valley below Swaby is very striking. Above the village, the valley-bottom is some 150 yards wide, and the valley-sides have the usual gently sloping outline of chalk hills. Below the village the valley is contracted to a trench-like ravine, the bottom of which is perhaps 40 yards wide, and its sides rise in steep slopes, the angle being in many places that of chalk débris (viz. 35°–38°).

The wider and older valley is actually continued southward through the village for some distance, the barrier of drift being about 400 yards beyond the point where the stream turns aside to enter the ravine. This modern continuation of the water-course is clearly therefore a new cut made through the solid mass of chalk, which originally formed one flank of the ancient valley.

It would seem that on the cessation of Glacial conditions the stream was able to occupy its former valley as far as Swaby, but being there ponded back it made it way over a col in the chalk hills which was lower than the surface of the drift barrier, and having once taken this course it would naturally maintain and deepen the new channel, forming the ravine above described.

The Glacial Clays and Gravels also occupy for some distance the valley of another tributary which joins the Calceby Beck south of Swaby. This stream also has cut into the chalk and runs in a small ravine for a distance of about three furlongs; but it is only just outside the limits of the drift area and is not so striking as the valley first described.

There can be little doubt that the ancient courses of the two brooks are concealed beneath the Glacial deposits; they probably united somewhere near Swaby Church, and thence the combined waters flowed south-eastward to join the main stream in the Calceby Valley.

Between Swaby and Burwell there are two very remarkable long and narrow valleys or ravines, the origin of which was for a long time a complete puzzle to me. The more westerly of these ravines pursues a winding course through the Chalk hills for a distance of about a mile and a half; its general appearance is that of a deep artificially-dug trench, for its sides slope at an angle of from 20 to 25 degrees, and the width of the flat floor at the bottom is on an average from 50 to 60 feet. Another peculiarity is that it is open at both ends, and that there is a watershed in the middle of it; its northern extremity opens into the Burwell Valley south of that village, and its southern end opens eastward into the continuation of the same valley near Swaby. In summer it is generally dry, but after much rain, pools collect at intervals, for the floor has not a uniform slope in either direction, and water soaks along its bottom towards one of the two outlets.

Its sides being too steep for cultivation, a great part of its course is utilised as a plantation. Altogether, I imagine there

are few more unique and apparently inexplicable valleys than this to be found in any part of England.

East of this is a second similar ravine, which, however, is much shorter and does not open outwards at both ends; indeed it commences abruptly about a quarter of a mile S.S.W. of the south lodge of Burwell Park and runs in a south-easterly direction for a distance of about five furlongs; its course is only slightly serpentine, and it opens into the same valley as the other. Its sides are grass slopes, and it is not quite so deep as the former.

It is not unreasonable to suppose that the longer of these ravines was the course taken by the water draining off the Burwell Hills before the excavation of the present valley between Burwell Park and Swaby; but the smaller ravine would still be a mystery, and there is the further fact to be considered, that these two are not by any means isolated instances, for many other similar valleys occur in the neighbourhood. Consequently any explanation must be a general one capable of being applied to every case, and not only accounting for the existence of one or two.

I proceed, therefore, briefly to notice the other valleys which come under the same category.

Between Burwell and Ruckland are two similar winding ravines, both of which open into a wider valley draining towards Burwell, but both are also open at the other end and appear, therefore, as narrow trenches communicating with three distinct valleys; the southern trench is the deeper and more striking; it is locally known as "Deep Dale," and is used as a plantation; seen from the Walmsgate Valley, into which it opens, the entrance to this gorge is a very remarkable feature and may be described as a miniature cañon.

Another similar ravine cuts completely through the broad ridge of chalk between Haugham and Tathwell; the watershed in this is near the centre, but springs are thrown out south of the farm near Orgarth Hill, which give rise to pools and marshes in the southern part of the valley. This is doubtless the locality mentioned by Camden in the following terms:—

"Haugham is remarkable for a hill called Skirbeck, from the side of which sometimes rushes out a torrent of water large enough to fill a circle of 30 inches in diameter. This stream continues to run with great rapidity for several weeks together from places where at other times there is no appearance of a spring. This irruption happens after long and heavy rains, perhaps once in a year or two."*

* Camden's Britannia, Gough's Edition, 1806, p. 383. From inquiries kindly made for me by Mr. C. A. Alington, Rector of Muckton, it would appear that the Skirbeck breaks out about six furlongs W.N.W. of Haugham Church, and some 100 yards east of the bridle road from Tathwell to Maidenwell. After heavy rains a large volume of water flows from it, running through a well-marked valley south of Haugham to Burwell, and sometimes flooding the road near the latter place. A similar winter-bourne issues near the farmstead at Maidenwell.

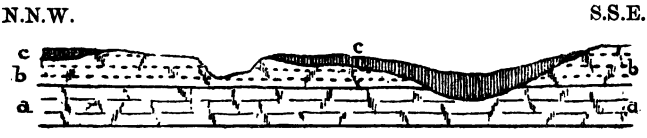
The most instructive case, however, is the group of similar narrow flat-bottomed ravines which trench the plateau between Burwell and Cawthorpe; these present a more complete system of drainage, and are clearly indicated on the geological map, because they seem everywhere to cut through the base of the chalk with flints, and the beds here are nearly horizontal. Though they shed water in different directions, and are open at both ends, yet the original drainage seems to have been towards Cawthorpe. The principal channel commences at the south corner of Burwell Wood and runs N.W. to Haugham Wood, where it receives two tributaries. The valley bottom is flat, but not level, having shallow depressions or basins where rushes grow, and which are, doubtless, hollows of solution or swallow-holes. I paced the width of the bottom at one place and found it to be 50 feet, the west side sloping to it at an angle of 20° to 25°, and the east side being rather steeper. At the S.W. corner of Haugham Wood there is a curious bulge in the valley, forming a kind of *cul de sac* with an oblong swallow-hole in the centre; it succeeds a very sharp bend in the valley, and has evidently been formed by the forcible rush of water in times of flood. In Haugham Pasture the channel takes a sharp horse-shoe bend, and here there is a large pond, probably marking the site of a swallowhole.

The ravine then runs north-east to Cawthorpe, crossing an older valley occupied by Boulder Clay in its course: in Cawthorpe Field the valley has been widened by drainage from either side, but quickly resumes the ravine-like form, and at Cawthorpe its continuation is clearly of Post-glacial date, for it trenches the Boulder Clay which there caps the Chalk; while the older valley which it previously crossed opens on to lower ground, and is filled with Boulder Clay. The mapping here suggested Fig. 23, as a diagrammatic section across the mouths of the two valleys.

FIG. 23.

Section across valleys at Cawthorpe.

Horizontal scale 4 inches to a mile.



c Boulder Clay. *b* Middle Chalk. *a* Lower Chalk.

Immediately outside the termination of the Post-glacial ravine at Cawthorpe strong springs gush out from the Chalk (see p. 95), and much of this water has doubtless percolated through the

Chalk along the bottom of the ravine which we have been following.

In order to arrive at a reasonable explanation of these curious ravines let us consider what aspect the surface of the Wolds would probably exhibit when the Glacial conditions had just passed away. I have shown in Chapter VII. that the Brown Boulder Clays are found not only in the valleys but also on the highest hills which form the eastern border of the Wold. It is tolerably certain therefore that the greater portion of the Chalk area was covered with a mantle of Boulder Clay, which invested hill and dale alike in one continuous sheet. Whether this sheet extended quite to the western edge of the Wold is not certain, but as this is nowhere much more than 400 feet high in Sheet 84 and the Brown Clay occurs at a level of 382 feet in Sheet 86, it is probable that very little of the Chalk area in our sheet was free from the clay covering.

Such being the case it is clear that the rain which fell on the surface would not soak into the Chalk as it does now, but would course freely over the land; the whole rainfall would consequently be made available for erosive purposes, and rain would be collected into rapid streams in situations where no water ever runs at the present time.

The course taken by these brooks and torrents would be determined by the irregularities in the surface of the Boulder Clay, and, once formed their channels, would be continually deepened until they reached the surface of the underlying Chalk: this also would be deeply trenched as long as so much of the clay mantle remained as sufficed to shed the greater portion of the rainfall into these channels. It is probable, however, that this mantle of clay was very thin on the higher ground, and as it was gradually removed by the general detrition of the surface a larger and larger area of bare chalk would be exposed and more and more of the rainfall would be absorbed.

In process of time a smaller number of channels would be sufficient for the drainage of the country, the action of springs would come into play, and would cause the extension and deepening of certain watercourses at the expense of others; thus some of the channels would remain nearly in their pristine condition, and the ravines above described, are I believe, such portions of these early channels as have not been destroyed by the subsequent detrition and valley erosion.

Two considerations are confirmatory of this explanation:

(1.) The strongest springs are thrown out on the western sides of the valleys and would lead therefore to their extension toward the west wherever that was possible;*

* Besides Skirbeck above mentioned, other strong springs always break out after heavy rains at Maidenwell and Burwell.

it would therefore be portions of ravines that ran at right angles to these which would be most likely to remain unoccupied. Now it is noticeable that the general direction of all the ravines is a longitudinal one, from south-east to north-west.

(2.) An examination of the ground in the neighbourhood of Burwell and Haugham Woods, where the most complete system of ravines is found, shows that this tract was one of the last to be divested of its covering of Boulder Clay and that a deep clay soil, 2 feet deep in places, still remains over the surface, while towards Muckton it becomes thick enough to map.

I am inclined to regard the valley between Burwell and Haugham as entirely of Post-glacial origin, and believe that a sheet of Boulder Clay spread continuously over this tract as far as Maidenwell. From the clay-covered tract the Haugham ravine would drain into the Tathwell Valley, the Deep-dale ravine into the Walmsgate Valley, and the ravines south-east of Burwell into Swaby Valley; all these being old Pre-glacial excavations.

From the fact that the streams have in so many instances re-occupied the pre-existent valleys, I infer that the original surface of the Boulder Clay was by no means level, but that, though it was naturally much thicker in the ancient hollows and depressions than on the hill tops, yet to a certain extent it draped the features of the former surface, and that the rain-rills were consequently directed into the depressions which marked the course of the ancient valleys.

This is well illustrated in the neighbourhood of Louth, where the Wolds are intersected by two ancient valley-systems both of which are still largely occupied with Drift deposits. The southernmost of these has several branches, two near Tathwell, which open into the valley running from Tathwell to Raithby, and two near Withcall, which unite between that place and Hallington. All these valley bottoms are occupied by Boulder Clay, and from Hallington, where the two main branches unite, the old clay-paved valley is continued eastward and opens on to the Boulder Clay plateau, a short distance south of Louth. It is clear therefore that when originally formed this valley had no connexion with the valley on the north side of Hubbard's Hill, which is now occupied by the River Ludd (see Fig. 24).

The modern streams which flow from the springs in the Tathwell and Withcall Valleys follow the course of these Valleys,* and unite near Hallington, flowing for a short distance to the north-east; the stream then curves to the north and entirely

* The Dovendale Beck, however, has made a new cut for itself half a mile in length.

deserting the ancient valley, it passes through the deep gorge below Hubbard's Hill, and joins the Welton stream (or Crake Beck) near Thorpe Hall. The Hallington Beck (which some consider as the main stream of the Ludd) has thus cut completely through the high ridge of chalk which once separated the two valley systems. Hubbard's Hill is 230 feet above O.D. and the bottom of the ravine below is about 100 feet; its depth therefore when deepest may be taken as about 130 feet.

FIG. 24.

Map of the valleys near Louth.

Scale, 1 inch to a mile.

The ground occupied by Drift is indicated by diagonal shading.

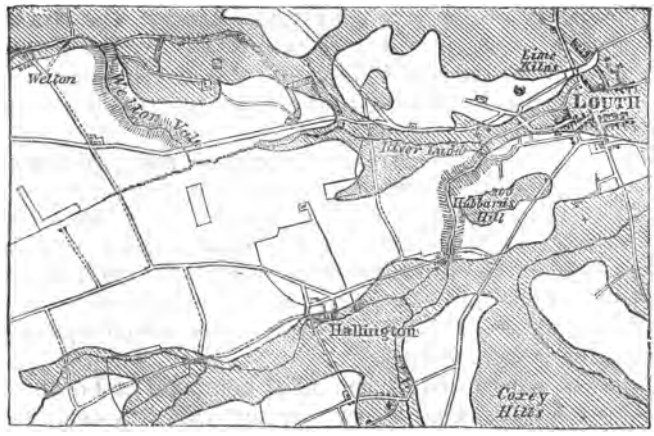
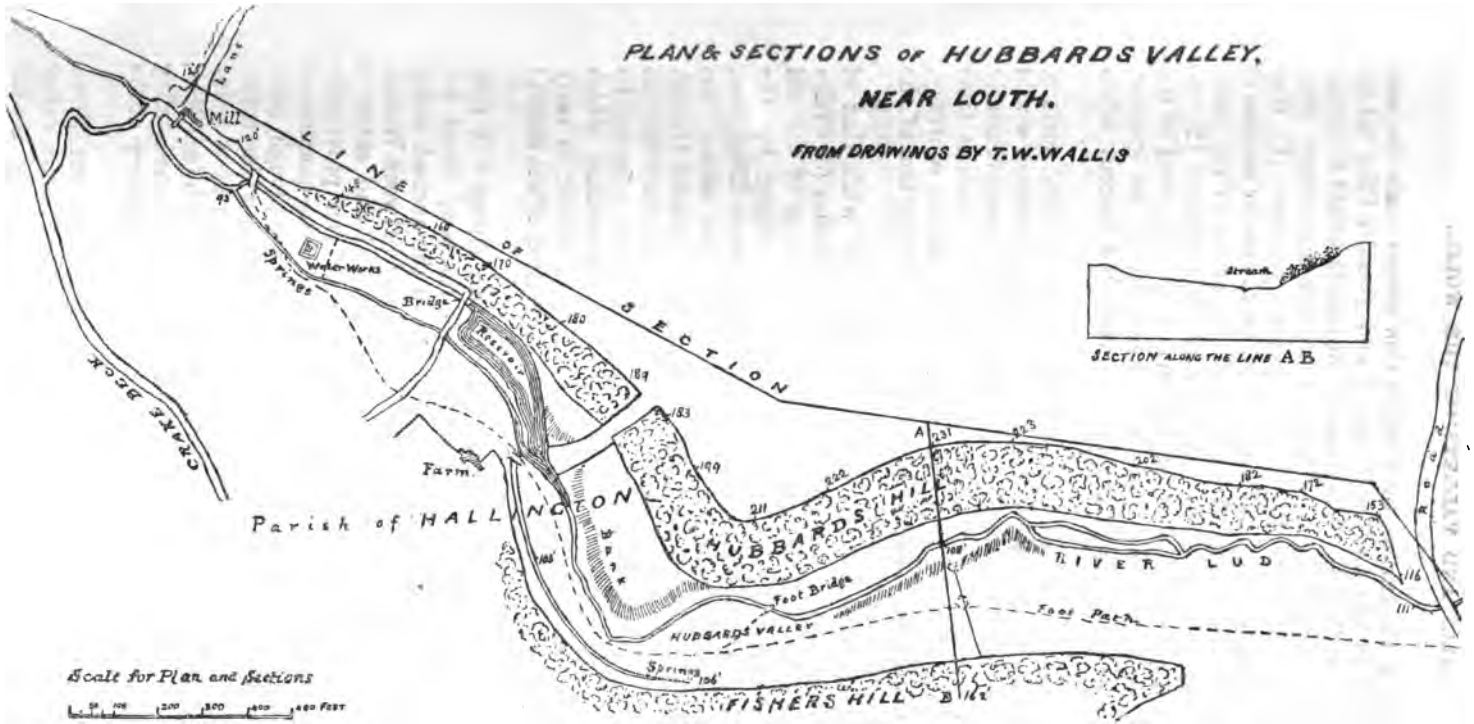


Fig. 24 is a general plan of the valleys near Louth; Hubbard's Vale is shown on a larger scale in Fig 25, which is reduced from a survey made by Mr. T. W. Wallis, of Louth.

To an observer standing on the Boulder Clay, which occupies the continuation of the old valley, and the surface of which is only some 20 feet above the bed of the stream, the view into the mouth of the gorge which the stream has cut for itself through the chalk is a very striking one. The origin of the ravine must seem utterly inexplicable except on the hypothesis that the pre-existent valley was once filled with Boulder Clay up to the level of the hill-tops, and that during the process of re-excavation the stream found it easier, on account of some local obstruction, to cut a channel northward over and through the Chalk, then eastward through the mounds of Boulder Clay.



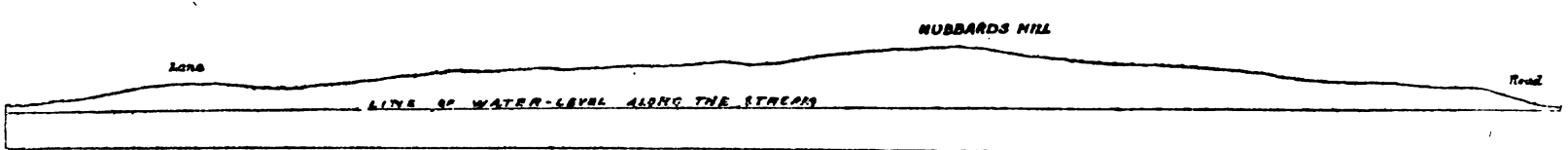


Fig. 25.

A remnant of the surface over which this stream made its way is to be found in the outlier of gravel and Boulder Clay which still caps Hubbard's Hill. The channel once made would be maintained and deepened, for the rate of erosion must have been much more rapid then than now for two reasons: (1) that already mentioned on p. 126, namely, the much greater volume of the stream in consequence of the greater proportion of the rainfall being shed into it from off the clay-clad surface; (2) the greater fall between the level of this surface and the level of the Marshland, causing the slope of the watercourse to be greater, so that the stream must have been a veritable torrent when there was much rain.

As the Boulder Clay was removed from the general surface, and as the depth of the ravine increased, both these factors would become less and the rate of erosion would proportionally diminish, till it gradually became *nil;* for at the present time the stream is not deepening its channel, but on the contrary, even allows alluvial detritus to accumulate at the bottom of the ravine towards its northern end.

Passing now to the valley which is continuous with that of the Ludd near Louth, we find that the modern stream (or Crake Beck) has made a similar departure from the course of the old pre-existent valley. The old channel can be traced by the Boulder Clay which occupies its bed as far as South Elkington, and a tributary of the Ludd still runs along this valley; but west of Elkington there are immense mounds of Glacial Gravel, partially mantled with Boulder Clay, which not only fill the valley but lap over and rest on the heights which bounded its southern flank. Here, therefore, was an obstruction which would be likely to bar the course of the stream which, in early Post-glacial times, was directed into the depression of the ancient valley.

Let us now follow the course of this modern stream: it rises near the village of Welton, just outside the limits of Sheet 84, and for the distance of about a mile it runs in the ancient valley over a bottom of Boulder Clay. About midway between Welton and South Elkington it suddenly turns southward and enters a narrow winding ravine like those which have been previously described. The length of this ravine is about three-quarters of a mile, and its sides, which are far too steep for the plough, have been laid out as plantations; it opens into a much wider valley running eastward and joining the older main valley at a point about one mile and a quarter west of Louth Church (see Map, Fig. 24). A tongue of Boulder Clay runs up this broad valley for about half a mile, proving it to have been a tributary of the ancient main valley.

The modern stream, therefore, has here made a new cut, three-quarters of a mile long, from the course of the old main valley into that of one of its tributaries, under exactly similar conditions to those described at Swaby and Hubbard's Hill.

The narrow wooded ravine above mentioned is known as Welton Vale, and is one of the sights of the neighbourhood of Louth. Its depth at the southern entrance is about 60 feet, and the sudden change from the ordinary scenery of open chalk valleys to a steep-sided ravine, which has more the aspect of a Yorkshire or Derbyshire vale, is very remarkable.

I have already remarked upon the tendency of the Post-glacial streams to occupy the valleys excavated by the Inter-glacial or Pre-glacial rivers, and have inferred that these were still depressions in the clay covered surface, and were not filled to the brim with Glacial deposits. It was only then at points in these valleys where these deposits happened to be heaped up in especially massive mounds that the stream was forced to take a different course and to excavate an entirely new channel for itself outside the limits of the old valley. In most cases the waters were probably ponded back, and a lake was formed, the level of which rose till it overflowed the lip of the enclosing basin where that lip was lowest.

I may conclude by pointing out that in our climate the mechanical wear of rain appears to remove the material of clay more rapidly than its chemical action removes the material of limestone. In Lincolnshire it certainly seems as if the Boulder Clays had wasted more rapidly under this influence than the Chalk; consequently the tops of the barriers which have caused the diversion of the streams are now in most cases much lower than the chalk hills through which the new ravines have been cut.

The simplicity of the geological structure of the district makes the demonstration of the comparatively recent origin of these ravines more easy and complete, so that they may be regarded as among the most interesting instances of river-erosion to be met with in England.

CHAPTER X.

ECONOMIC PRODUCTS AND WATER SUPPLY.

Building Stones.—This part of Lincolnshire possesses only two rocks which are capable of being used as a building material, namely, the Spilsby Sandstone and certain beds of the Grey Chalk.

The Spilsby Sandstone is a fine greenish sandstone, weathering brown, which can be easily quarried as a freestone, but appears to vary much in quality; some blocks of it have lasted very well, but others have decayed and crumbled. It has been used in the construction of nearly all the older churches, and the principal quarries seem to have been at Salmonby and at Holbeck, near Ashby Puerorum. The latter were noticed by Camden, who says:—

"In this parish (Holbeck, near Ashby Puerorum) are rocks of sandstone, and a great number of pits, which, from their size and depth, must have been the consequence of vast labour and expense. There is no visible reason for this appearance near the place, and it is difficult to account for it, unless the neighbouring churches (which for many miles round are built of this sort of stone) were dug out of quarries formerly worked here."*

There are also old quarries in Harrington Carrs. It is possible that these localities were chosen for the opening of quarries, because they were accessible along the valley of the Calceby Beck, which forms a natural pass through the Wolds. By this route the stone could be more easily conveyed into the eastern lowlands than by any of the hill roads.

It has been already mentioned (p. 58) that one of the beds of the Lower Chalk quarried near Louth has been sometimes used as a building stone. This bed is about 4 feet thick, and consists of a hard grey chalk containing a certain admixture of fine silt, and resembles the Totternhoe Stone in lithological composition; it separates by jointing into natural blocks, and these, when trimmed, have been used in some of the older buildings near Louth, though I could not learn whether it was ever so employed now. An analysis of this stone has been made by Mr. Grant-Wilson, with the following result:—

* Camden's Britannia, Gough's Edition, 1806, p. 383.

Insoluble in HCl.:		
Silica	5·26	
Alumina	1·41	
Peroxide of Iron	·16	
Loss on Ignition	1·19	8·02
Soluble portion:		
Alumina	·31	
Protoxide of Iron	1·10	
Protoxide of Manganese	·15	
Lime	48·89	
Magnesia	·73	
Carbonic Acid	38·51	
Phosphoric Acid	·29	
Water	1·64	91·62
		99·64

In speaking of the hard grey chalk of Lincolnshire, of which this bed forms a part, Professor J. W. Judd remarks:*—"This stone, as in Norfolk, has been extensively employed as a building material, and even for the purpose of sculpture. Thus a great part of Louth Abbey, erected in the twelfth century, is constructed of this material; and it is a noteworthy fact that while some of the stones have decayed and fallen almost to powder, others have as sharp edges and exhibit the tool-marks as perfectly as if but yesterday brought from the quarry. Probably by exercising care in the selection of particular beds, and in laying the blocks in their natural positions, this rock might still be made to furnish a very serviceable building stone."

Iron Ores.—Ironstone occurs at two horizons in the Tealby Series (see Chapter III., p. 19.), but is variable in thickness and quality. The lower bed is thickest beneath the outlier of Hundleby, near Spilsby, and the following is an analysis by Mr. Grant-Wilson, of the rock from Hundleby Brickyard:—

Insoluble in HCl.:		
Silica	21·38	
Alumina	2·34	
Protoxide of Iron	·27	
Magnesia	·05	
Loss on Ignition	·36	24·40
Soluble portion:		
Alumina	6·10	
Protoxide of Iron	11·60	
Peroxide of Iron	11·20	
Protoxide of Manganese	·36	
Lime	19·20	
Magnesia	1·93	
Carbonic Acid	23·72	
Sulphuric Acid	·03	
Water	·69	74·83
		99·23

* Quart. Journ. Geol. Soc., vol. xxiii, p. 236.

It is evident from this analysis that the iron was originally in the condition of a carbonate, a certain portion of which has been oxidised by the percolation of water; and it is probable that in the central portion of the mass, which is grey in colour and very hard, nearly the whole of the iron remains in the carbonated condition. Although the amount of iron is not large, yet it is an ore which might possibly serve for smelting, the extremely small amount of Sulphuric Acid and the absence of Phosphoric Acid telling in its favour. Unfortunately, the area over which it is known to extend within anything like a workable distance is rather small, but further exploration might result in the discovery of a similar bed at other localities; there is little doubt that it occurs also beneath Marden Hill, near East Keal.

Irregular beds of ironstone also occur in the "Roach" at the top of the Tealby Series, this roach being itself a yellow ferruginous marl full of oolitic grains of iron ore. Harder and more compact ferruginous beds meriting the name of ironstone occur in this rock at Skendleby and Langton, Mr. Grant-Wilson has made an analysis of a sample taken from the Spring Head near Skendleby Lodge, which gave the following results:—

Insoluble in HCl.:	
(Chiefly Silica)	16·92
Soluble portion:	
Alumina	12·09
Protoxide of Iron	20·42
Protoxide of Manganese	1·87
Lime	27·05
Magnesia	·78
Carbonic Acid	5·40
Phosphoric Acid	13·50
Sulphuric Acid	·04
Water	·56
	98·63

Phosphatic Nodules.—The layer of rolled phosphatic nodules which occurs at the base of the Spilsby Sandstone (see p. 14) might in some places be worth working for commercial purposes. The nodules, however, seem to vary in quantity and quality at different localities, and appear to have been derived from more than one original location. Some consist of a very dark, nearly black, material, and these are probably the richest in phosphate, others are of a light brown colour, and some contain a considerable admixture of sand. The value of any sample will probably depend upon the proportion of dark nodules; for the following analysis, of a sample from East Keal, I am indebted to Mr. M. Staniland;—

Insoluble residue	37·94
Lime	29·91
Phosphoric Acid	21·37
Carbonic Acid, Alumina, Oxide of Iron, &c.	6·78
Moisture	4·00
	100·00

From this the following amounts may be calculated:—

Phosphate of Lime	46·65
Carbonate of Lime	8·21

Another sample from the same place, partially analysed by Mr. Grant-Wilson, yielded 21·38 per cent. of Phosphoric Acid, which is confirmatory of the above analysis. The quality of these nodules is therefore comparable to those of Potton and Wicken.

A sample of the scattered and broken nodules found in the Carstone at Gaumer Hill was partially analysed by Mr. M. Staniland with the following result:—

Insoluble residue	23·00
Phosphoric Acid	23·57
Lime	32·78

from which the following amounts may be deduced:—

Phosphate of Lime	51·45
Carbonate of Lime	8·75

Water Supply.

This part of Lincolnshire is fortunate in the matter of water supply; fine natural springs are very frequent, and there are very few places where good water is not obtainable by sinking to a reasonable depth.

The lowest water-bearing bed is the Spilsby Sandstone (Neocomian), and the number of villages situated on the outcrop of this sandstone testifies to the goodness of the water supply. Strong springs gush out at many points along the line of its junction with the underlying Kimeridge Clay, especially in the dales on the western side of the Steeping Valley. Two of these springs have attained special celebrity, namely, the "Lady Well" in Colonel Valentine's grounds at West Keal and the "Holy Well" at Somersby. The former is remarkable as showing how small a collecting area will suffice for the support of a perennial spring, for the gathering-ground is less than a quarter of a square mile in extent, say about 150 acres, and the thickness of the sandstone is nowhere more than 35 feet.

The water which percolates through the Chalk is thrown out either in the Red Chalk at its base or in the underlying Carstone more frequently, however, in the former on account of the thin layers of red, green or grey clay which often occur at the

junction of the Carstone and Chalk. Sometimes water oozes out along the line of junction for a distance of many yards, but more usually it issues in considerable quantity at a single spot which is always in a deep recess or at the head of a valley. The part played by these springs in producing these features has been noticed in a previous Chapter (pp. 24, 45).

On the Chalk Wolds no water is obtainable without sinking through the Chalk into the Carstone, and along the central part of the range or watershed the supply so obtained is often very small, and runs short in the summer time, although the springs at the outcrop continue as usual. This is the case along the high ground near Ulceby and Driby High Barn, west of Alford, where the Chalk is over 200 feet thick. The reason of this is probably that the water which falls on the Chalk, and reaches the base of that rock, makes its way quickly either to the west or east, so that in dry seasons little is left along the central line beneath the watershed. In the winter the supply is generally abundant, and where the Wolds are trenched by deep valleys, as near Burwell, Haugham and Maidenwell, intermittent springs and winter-bournes often make their appearance; an account of one of these, the Skirbeck, has been given in a previous Chapter (p. 124).

Other sources of water supply are the strong springs which break out on the eastern slopes of the Wolds, along the line where the Boulder Clay is banked up against the cliff or steep slope of Chalk. As the depth of Boulder Clay at a few hundred yards distance from the boundary line is from 60 to 90 feet, it is evident that this impervious mass obstructs the flow of the water which is percolating eastward through the chalk, and forces much of it to the surface; the result is that a number of perennial springs, affording an excellent and abundant supply of water, break out at those points along the line where the level of the ground is lowest, and generally where one of the dry valleys that trench the Wolds opens on to the Boulder-clay plain. It may be useful to give a list of these here, commencing with the southernmost:—

1. At Welton, west of the Church.
2. At Claxby, about 300 yards west of Church.
3. At Well, one furlong N.E. of Church.
4. At Haugh, about six furlongs N.N.W. of Church.
5. At Belleau, between the Church and the Hall.
6. At Muckton, 200 yards N.E. of Church.
7. At Cawthorpe, by roadside below the Church.
8. At Louth, Aswell, and St. Helen's springs.
9. At North Ormsby, near the Church.

Besides these strong springs are thrown out under similar circumstances at Tathwell, Maltby, Raithby, Withcall, Welton-on-

Wold, and at the Silver Springs west of Louth, where the town waterworks are situated.

The Claxby springs were suggested as a source of water supply for Skegness, if the result of the recent boring operations there did not prove satisfactory.

The spring at Well also yields an unfailing supply of pure water. Mr. Cartwright, of Well, informs me that the water of the pond which it supplies is always cool in summer, and has never been known to freeze in winter. The temperatures taken on July 2, 1878, were, of the spring at point of issue 50° F., of the water in the pond 54° F., that of the air at the time being 60° F.

The Belleau springs are famous, the very name of the place being derived from the "fine spring." They gush out from below a steep cliff-like slope of chalk, capped by glacial loam and gravel. The name was probably given by the monks of Belleau Abbey when they determined upon the spot as a site for the erection of their monastery.

Aswell and St. Helen's springs, which are near one another, about a quarter of a mile S.E. of Louth Church, are also celebrated; and the monks of Louth Abbey (built in the 12th century) constructed a raised waterway from St. Helen's spring to the Abbey, a distance of nearly two miles. This still exists and is known as the Monk's Dyke.

East of the Wolds on the clay plateau and in the marsh, water is always obtained by sinking through the Glacial and Post-glacial beds to the Chalk which underlies them; artesian wells are then formed, the water rising up in the bore, and in some parts of the marshland overflowing. The depth of these artesian wells varies from 50 or 60 to more than 100 feet, according the level of the surface and the distance of the spot from the Chalk Hills. The surface of chalk beneath the Glacial Beds seems to be very even on the whole, but slopes gently eastward, so as to lie at a depth of about 80 feet below ordnance datum level along the coast line.

The water obtained in the marsh clays and silts is generally salt, but along the landward edge of the sand hills which border the coast fresh water is often obtained in shallow wells. This is the case at Skegness, Sutton, Mablethorpe, and other places, and there can be no doubt that the supply is derived from the local rainfall stored up at the base of the sand hills, though the width of these is in many places less than 100 yards. The supply is generally sufficient for the cottages built near the sand hills and only fails in very dry seasons.

[1] *Flint Implements.*—At West Keal, in the fields to the west of the spring known as Lady Well, there seems to have been an atelier or manufactory of flint implements in Neolithic times.

Quantities of small flint flakes and chips are strewn about the fields, together with a few cores and several round or oval flints, chipped carefully round the edges, and possibly used as "strike-a-lights." Colonel V. Grantham, of West Keal, has many of these flints in his possession, and some of them appear to have been used or worked up by chipping along the back. He also informed me that a smooth celt and two arrow-heads had been found in a field near the Church.

The spot has a dry sandy soil, a southerly aspect, an unfailing spring in close proximity, and a commanding view over the Fens, which were doubtless the hunting-ground of the tribe who chipped their flints on West Keal Hills.

APPENDIX A.

PALÆONTOLOGY.

Of the fossils in the following lists those from the Nodule-bed (Table I.) were collected by Mr. M. Staniland and myself. Those from the Neocomian Sandstone and Clays near Spilsby (Tables II., III., IV.) were collected by Mr. Rhodes. Those from the Red Chalk and basement beds of the Grey Chalk (Tables V. and VI.) were collected partly by Mr. Allen and partly by myself. Those from the higher beds of the Chalk were obtained at different times and places by Mr. Allen, Mr. Rhodes, and myself. The species have been determined by Mr. G. Sharman and Mr. E. T. Newton.

The few fossils that have been found in the Kimeridge Clay are given in the Chapter describing that formation.

TABLE I.

Fossils from the Nodule Bed at the base of the Neocomian.

	N. of Baithby.	Aswardby.	Stockworth Mill.	Somersby and Enderby.
Terebratula ovoides, *Sby.*	- -	- -	- -	×
Waldheimia Woodwardii	- -	- -	- -	×
Arca sp.	×	×		
Astarte	- -	- -	- -	×
Cyprina	- -	- -	- -	×
Cucullæa sp.	- -	- -	- -	×
Myacites recurva	×	×	×	×
Isocardia ?	- -	- -	×	×
Lima sp.	- -	×	- -	×
Lucina Portlandica, *Sby.*	×	×	×	×
Pectunculus sp.	- -	- -	×	
Thracia Phillipsii, *Rom.* (or depressa, *Sby.*)	- -	- -	- -	×
Trigonia sp.	×			
Natica sp.	- -	- -	- -	×
Pleurotomaria	- -	×	- -	×
Ammonites biplex, *Sby.*	×	×	×	×
„ plicatilis	- -	- -	×	×
„ speetonensis *Y. & B.*	- -	×	×	
Belemnites sp.	×			

The only specimen among these which retains the shell and which therefore may not be derived is one of *Am. speetonensis*. With regard to the rest it must be mentioned that being rolled casts their identification is in some cases difficult. Thus the *Myacites recurva* might equally well be *Panopœa neocomiensis*, and on the other hand *Thracia Philipsii* may well be *Th. depressa* of the Kimeridge Clay. There can be no doubt that most of the phosphates have been derived from the Kimeridge Clay, but it is just possible that there were certain older Neocomian beds (destroyed before the deposition of the Spilsby Sandstone), and that some of the casts were derived from them. More material is required before this question can be decided.

TABLE II.

Fossils from the Spilsby Sandstone.

——	Toynton All Saints.	West Keal.	Bolingbroke.
Belemnites lateralis, *Phil.*	×	×	
Ammonites plicomphalus, *Sby.*	×	×	×
„ near rotundus, *Sby.*	- - -	- - -	×
Trochus	- - -	×	
Pleurotomaria	- - -	×	×
Pecten orbicularis ?, *Sby.*	×	×	×
Pinna	- - -	- - -	×
Astarte	- - -	- - -	×
Lucina lirata, *Phil.*	- - -	- - -	×
„ crassa ? *Sby.*	- - -	- - -	×
Trigonia tealbyensis, *Lyc.*	×	×	×
„ near Moretoni, *Lyc.*	- - -	- - -	×
„ near alina, *Lyc.*	- - -	- - -	×
„ (clavellate form)	- - -	- - -	×
Panopæa neocomiensis ?, *Leym.*	- - -	- - -	×
„ sp., A.	×	×	×
Inoceramus neocomiensis ?	×		
Lima, sp.	- - -	- - -	×

The above is a remarkable assemblage of fossils, and one which is sufficient to raise doubts as to the essentially Cretaceous age of the sandstone containing them. It is desirable therefore to discuss each species separately.

Belemnites lateralis.—The form which is not uncommon in the sandstone certainly resembles this species more than any other known Belemnite.

Ammonites plicomphalus.—The type of Sowerby's species came from the neighbourhood of Bolingbroke, and was doubtless procured from this sandstone. A species from the Kimeridge Clay has been identified with it. I have not had an opportunity of comparing specimens from the two formations, but in view of the Jurassic affinities exhibited by the other fossils of the sandstone I should think that their close alliance is very probable.

Ammonites rotundus.—This is a Kimeridge Clay form, and Mr. Sharman finds that the specimens from the Spilsby Sandstone approach it very closely. Mr. W. Keeping records *Ammonites mutabilis* (a Kimeridge species) and *Am. Kœnigi* (an Oxfordian and Kimeridge species) as occurring in this sandstone near Donington in Sheet 83. This is quite possible, but the identifications need confirmation.

Pecten orbicularis ?—Mr. Sharman in writing to me says, "Again very many of the Pectens, which one would naturally believe to be *Pecten orbicularis*, have such a marked resemblance to *P. demissus* of the Upper Oolites that it is almost impossible to say to which of the two species they belong, and we have failed to find any specimen among the number showing the concentric ornamentation so characteristic of one valve of *P. orbicularis*."

Lucina lirata.—This is a Kellaway's species, but Mr. Sharman informs me that the specimen from Bolingbroke is identical with the *L. lirata* of Phillips. The original specimen of *L. crassa*, Sby., non Morris, came from these same beds near Horncastle.

Trigonia tealbyensis is at present only known from Lincolnshire specimens, and therefore affords no help in correlation. The two species listed as comparable to *T. Moretoni* and *T. alina* respectively are doubtless new species, and these names are only introduced to convey an idea of the general appearance of the shells. *T. Moretoni* is a Great Oolite and Cornbrash species, and *T. alina* is a doubtful form. Mr. Sharman informs me that the clavellate form appears to be intermediate between *T. ingens* of the Neocomian and *T. incurva* of the Kimeridge Clay.

Panopæa neocomiensis.—A form referable to this species has been met with at Bolingbroke, but another species resembling *Myacites recurva* of the Kimeridge Clay occurs at every locality.

Mr. Sharman sends me the following notes on this assemblage of species found in these calcareous concretions:—

"It may be well to call attention to the additional evidence obtained by Mr. Walter Keeping regarding the fossils from these beds*. The list of fossils obtained from the hardened sandstone masses in the neighbourhood of Donnington and Claxby include both Oolitic and Neocomian forms, the more important of which are given below, marked K, those marked S having been collected by the Geological Survey—

Oolitic Species.	Peculiar to the Calcareous Concretions.	Neocomian Species.
K Ammonites mutabilis, *Sby.*	K Ammonites plicomphalus, *Sby.*	K Ammonites multiplicatus *Roem.?*
K Ammonites Kœnigii, *Sby.*	K Trigonia Keepingii, *Lycett.*	K Lima tombeckiana, *D'Orb.*
	K Trigonia tealbyensis, *Lycett.*	K Trigonia robinaldina, *D'Orb.*
	K Cucullæa donningtonensis, *Keeping.*	
	K Cucullæa errans, *Keeping.*	
	K Pecten orbicularis, *Sby.*, var. magnus, *Keeping.*	
S Ammonites rotundus, *Sby.*	S Lucina crassa, *Sby.*	S Belemnites lateralis, *Phil.*
S Trigonia, near to T. Moretoni, *Lycett.*	S Trigonia tealbyensis, *Lycett.*	
S Trigonia, *two* clavellate forms.	S Ammonites plicomphalus, *Sby.*	
S Lucina lirata, *Phil.*		

"Judging from survey specimens alone there is a preponderance of Oolitic forms, but Mr. Keeping gives a greater proportion of Neocomian forms. The stratigraphical evidence, it seems, points to these beds as being of Lower Neocomian age, but the fossils they have yielded form a very distinct group with strong Oolitic affinities. It is tolerably evident, therefore, that these "Calcareous concretions" occupy a lower horizon than any Neocomian beds hitherto described, and in so far as Palæontological evidence goes seem to occupy an intermediate position between the Lowest Neocomian and the Uppermost Oolites."

TABLE III.

Fossils from Oolitic Ironstone, Hundleby Brickyard near Spilsby.

Waldheimia tamarindus, *Walker.*	Astarte, sp.
Exogyra conica, *Sby.*	Cucullæa gabrielis, *Leym.*
Lima (new sp.).	Pholadomya Martini, *Forbes.*
Pecten cinctus, *Sby.*	Pholas (large sp.).
,, striato-punctatus, *D'Orb.*	Belemnites lateralis, *Phil.*

It is interesting to note the great difference between this assemblage and the fauna of the underlying sandstone, only one of the named species (*Belemnites lateralis*) being common to both. The facies of the ironstone fauna is characteristically Neocomian.

* The Fossils and Palæontological Affinities of the Neocomian Deposits of Upware and Brickhill, Sedgwick Prize Essay for 1879, p. 64.

TABLE IV.

Fossils from the base of the Tealby Clays.

—	East Keal Brick-yard in Blue Clay.	Hundleby Brick-yard in Calcareous Nodules.
Wood	×	
Terebratula sella, *Sby.*		×
Avicula		×
Exogyra conica, *Sby.*		×
Inoceramus	×	×
Pecten orbicularis, *Sby.*	×	
„ striato-punctatus, *D'Orb.*		×
Astarte	×	× (clay)
Cardita	×	
Corbis?	×	
Corbula	×	
Cucullæa	×	×
Cardinia		×
Myacites?		×
Panopæa neocomiensis, *Leym.*	×	×
Leda scapha, *d'Orb.*	×	× (clay)
Thetis Sowerbyi, *Röm.*	×	×
Thracia elongata, *Röm.*	×	
Pholadomya Martini, *Forbes*		×
Trigonia ingens, *Lyc.*	×	
Ammonites speetonensis, *Y. & B.*	×	×
„ gowerianus? *Sby.*		×
Belemnites lateralis, *Phil.*	×	

This assemblage is also eminently Neocomian, with the exception of the Ammonite doubtfully named *Am. gowerianus*; this also resembles a globose form of *Am. astierianus*, and seems to be intermediate between the two species. As it occurs in a nodule with fragments of *Goniomya* and *Cardium* it may possibly be a derived fossil.

TABLE V.

Fossils from the Red Chalk or Hunstanton Rock.

Obtained from many localities along the line of outcrop—

Vermicularia, sp.
Terebratula biplicata, *Sby.* (common).
„ capillata, *D'Arch.*
„ semiglobosa, var. undata, *Sby.*
Rhynchonella lineolata, *Phil.* (rare).
Kingena lima, *Defr.*
Ostrea vesicularis, *Lam.* (small).
Avicula gryphæoides, *Sby.* (common).
Pecten quinque-costatus, *Sby.*
Plicatula minima, *Seeley.*
Spondylus truncatus?, *D'Orb.*
Inoceramus tenuis, *Mant.*
„ sp.
Belemnites minimus, *Lister* (common).

TABLE VI.

Fossils from the lower part of the Lower Chalk.

—	Pit near Candleby.	Grebby.	Dalby and Langton.	Sutterby and Brinkhill.	Other Localities.
Serpula, sp. (or Vermicularia)	×	-	-	×	×
Cidaris, sp.	×	-	-	×	×
Discoidea cylindrica, *Lam.*	×	×	×		
Goniaster, sp.	-	-	×		
Holaster lævis	×				
„ subglobosus, *Leske*	×	×	×	×	
Echinocorys vulgaris, *Beyn* (Ananchytes ovatus, *Lesk*) (globose form)	×	-	-	-	× ?
Pseudodiadema variolare, *Ag.*	-	×			
Terebratula biplicata, *Sby.*	×	×	×	×	×
„ semiglobosa, *Sby.*	×	×	×	×	×
Terebratulina gracilis, *Schloth*	×				
Rhynchonella Cuvieri, *d'Orb*	×	×	×	×	×
„ mantelliana, *Sby.*	×				
Ostrea vesicularis, *Lam.*	×	×	×	×	×
Exogyra conica ?, *Sby.*	-	-	-	×	
Anomia, sp.	-	-	-	×	
Pecten orbicularis, *Sby.*	×	-	-	-	×
Plicatula inflata, *Sby.*	-	×	×		
Avicula gryphæoides, *Sby.*	-	-	×	×	
Lima echinata, *Eth.*	×	-	×	×	
„ globosa, *Sby.*	×				
Inoceramus Cuvieri ?, *Sby.*	-	-	×	×	×
„ mytiloides ?, *Mant.*	-	-	-	-	×
„ latus, *Mant.*	-	×	×	×	
„ striatus, *Mant.*	×	×	×	-	×
Ammonites navicularis, *Mant.*	-	-	×		
„ varians	-	-	-	×	×
„ sp. (large)	×				
Turrilites scheuchzerianus, *Bose.*	×				
„ tuberculatus ?, *Bose.*	-	-	-	×	
Otodus, sp (tooth)	×				
Fish vertebræ	×				

This fauna corresponds very closely with that of the Totternhoe Stone and of the beds immediately above and below that horizon in Cambridgeshire; the Cephalopods are such as are usually found in the upper part of the Chalk Marl and in the Totternhoe Stone. The *Anomia* is probably *A. papyracea*, which, with *Lima echinata*, is characteristic of that stone, as is also *Pecten fissicosta*, which was found at Louth in rather higher beds (see Table VII.). The only species in the above list which does not belong to the Totternhoe fauna is *Ananchytes ovatus*, but notice of this will be taken in the sequel.

TABLE VII.

Fossils from the central beds of the Lower Chalk, below the first pink band.

	Uleeby.	Thoresby and Swaby.	Hallington.	Hubbard's Vale, Louth.	North side of Louth.
Vermicularia umbonata, *Mant.*	-	-	×	-	×
Discoidea cylindrica, *Lam.*	-	-	×	-	-
Holaster subglobosus, *Leske.*	×	-	×	×	-
Pseudodiadema (spine)	-	-	-	-	×
Rhynchonella Cuvieri, *d'Orb.*	×	-	×	-	×
„ Martini, *Mant.*	-	-	×	×	-
„ mantelliana ?, *Sby.*	-	-	×	×	-
Terebratula biplicata, *Sby.*	×	-	×	×	×
„ semiglobosa, *Sby.*	×	×	×	×	×
Terebratulina gracilis, *Schloth.*	-	-	-	-	×
Inoceramus sp. (? mytiloides)	×	×	×	-	×
Ostrea vesicularis, *Lam.*	×	×	×	-	×
Pecten orbicularis, *Sby.*	-	-	×	×	×
„ fissicosta, *Eth.*	-	-	-	×	-
Lima globosa, *Sby.*	-	-	-	×	×
„ echinata, *Eth.*	-	×	-	-	-
Plicatula inflata, *Sby.*	×	-	-	-	×
Teredo amphisbæna, *Goldf.*	-	-	-	-	×
Ammonites Austeni, *Sharpe*	-	-	-	×	-
„ ? peramplus, *Mant.*	×	×	×	×	-
„ rhotomagensis *d'Orb.*	-	-	×	-	-
Hybodus (tooth)	-	-	-	-	×
Lamna plicatella, *Reuss*	-	-	-	×	-
„ subulata, *Ag.*	-	-	-	-	×

TABLE VIII.

Fossils from the upper beds of the Lower Chalk.

	Claxby and Welton.	South Thoresby.	Hallington.	Louth.
Brachiolites?	- -	- -	- -	+
Serpula antiquata?, *Sby.*	- -	×	×	×
Echinocorys vulgaris, *Breyn* (Ananchytes ovatus), *Leske* (globose form)	×	×	- -	×
Cidaris sceptrifera, *Mant.*	- -	- -	- -	×
„ sp.	×			
Discoidea cylindrica, *Lam.*	×	×	×	×
Goniaster	×			
Holaster subglobosus, *Leske*	×	×	×	×
„ trecensis?, *Leym.*	×	- -	- -	×
„ lævis, *Deluc* (like planus)	- -	- -	- -	×
Terebratula biplicata, *Sby.*	×	- -	×	×
„ semiglobosa, *Sby.*	×	×	×	×
Magas pumilus, *Sby.*	- -	- -	- -	×
Terebratulina gracilis, *Schoth.*	- -	- -	- -	×
Rhynchonella Cuvieri, *d'Orb.*	×	- -	×	×
Ostrea acutirostris, *Mills*	×			
„ vesicularis, *Lam.*	×	×	×	×
Avicula gryphæoides, *Sby.*	- -	- -	- -	×
Exogyra conica, *Sby.*	×	- -	- -	×
„ haliotoidea, *Lam.*	- -	- -	- -	×
Inoceramus Cuvieri?	×	×		
„ mytiloides, *Mant.*	×	×	× ?	×
Ammonites peramplus, *Mant.* (large flat var.)	- -	- -	- -	×
Otodus	- -	×		
Oxyrhina	- -	×		
Ptychodus decurrens, *Ag.*	- -	×	- -	×

In collecting from the chalk with pink beds near Louth, Mr. Rhodes, at my desire, kept the fossils he found in the pink beds apart from those obtained from the grey and white chalk above and between them, in order that we might see if any species were peculiar to the coloured beds. The result showed that there was no difference whatever, all the species found in the pink beds being also found in the whitish beds. The fauna of the grey beds below the first pink band, however, is somewhat different, 14 species occurring in them which do not recur in the higher beds, and 10 species being found in the latter which do not occur in the former. From a comparison of Tables VI. and VII., it is evident that the lowest beds exposed near Louth contain a similar assemblage to that of the chalk above the *Inoceramus* beds at the south end of the Wolds.

TABLE IX.

Fossils of the Middle Chalk, near Louth.

1. *From the Marl-band (Grey and Purple).*

Ostrea vesicularis, *Lam.*
Terebratula biplicata, *Sby.*
Rhynchonella lineolata, *Phil.*
Coprolite of fish.
Otodus (tooth).
Ptychodus decurrens, *Ag.*
Chelone, sp.

2. *From Hard Chalk without Flints.*

Rhynchonella Cuvieri, *D'Orb.*
Terebratula biplicata, *Sby.*
,, semiglobosa, *Sby.*
Ostrea vesicularis, *Lam.*
Inoceramus Brongniartii, *Sby.*
,, Cuvieri?, *Sby.*
,, mytiloides, *Mant.* (common).
Holaster trecensis?, *Leym.* (near Raithby).
,, subglobosus, *Leske* (near Driby).
Ammonites, sp.

3. *From White Chalk with Flints.*

Terebratula semiglobosa, *Sby.*
Rhynchonella Cuvieri, *D'Orb.*
,, limbata, *Schloth.*
,, lineolata, *Phil.*
Ostrea vesicularis, *Lam.*
Inoceramus mytiloides?, *Mant.*
,, involutus, *Sby.*
,, Cuvieri, *Sby.*
,, Brongniartii, *Sby.*
Echinoconus globulus, *Desor.*
Infulaster excentricus, *Rose.* var.
Hippothoa elegans, *D'Orb.*

Another result of the collections made in Lincolnshire is to show that the distribution of species in the Chalk of that county is somewhat different from the distribution which appears to prevail in more southern counties. Thus, while the general assemblage of species in the Lower Chalk of Lincolnshire is the same as that found in the zone of *Holaster subglobosus* elsewhere, yet there are also present several species, which in Cambridgeshire and the South of England do not occur at so low an horizon, but are

apparently confined to the higher parts of the chalk. These species are *Ananchytes ovatus*, which has not been found below the Chalk Rock. *Ammonites peramplus*, *Inoceramus Cuvieri*, and *Cidaris sceptrifera* which are species belonging to the Middle Chalk of Southern England.

Again the list of fossils from the Lincolnshire Chalk with flints contains species which are elsewhere confined either to the lower beds of the Middle Chalk (e.g. *Echinoconus globulus*) or to the higher beds (e.g. *Infulaster excentricus*).

It is possible that the zonal distribution of forms in the Norfolk Chalk (when worked out) may throw some light upon these anomalies, and until this has been done it will be impossible to bring the Lincolnshire zones into clear correlation with those which have been established in Cambridgeshire.

APPENDIX B.

WELL SECTIONS AND BORINGS.

Aby, near Claythorpe. Well at the blacksmith's house.

Information obtained on the spot.

	feet.
Dug through clay into gravel	26

Alford. Well at Mr. Soulby's brewery, yielding a good supply of water.

Communicated by Messrs. Baker & Son.

	ft.	in.
Gravel	8	6
Clay [Boulder Clay]	20	6
Black rock [? a boulder]	0	6
Black pebbles	2	0
Red rock [a boulder]	0	4
Pebbles	1	6
Ironstone [a stone]	0	2
Pebbles	2	6
White rock [a boulder]	0	6
Silt	2	0
Chalk and Chalk rock	26	8
Clays	—	
Shingle	—	
Sand	—	

No record was kept of the beds lying below the chalk, but if clay was found immediately below, this is probably Boulder Clay, and the chalk must be a large mass included in the glacial deposits. The succession may be summarised as follows:—

	ft.	in.
Gravel	8	6
Boulder Clay	20	6
Gravel, with large stones and fragments of rock	7	6
Silt	2	0
Chalk (an included mass)	26	8
Boulder Clay perhaps	10	0
Sand and shingle perhaps	3	0
About	78	0

Alford. At Mr. Lewis' house S.W. of the Church.

Communicated by J. Bingley, of Aby (well-sinker).

	feet.
Sandy gravel	8
Stiff clay	22
Sand and water	6
Marly clay	15
Chalk	22
	73

ALFORD. In the new road about two furlongs S.W. of the Church.

Communicated by J. BINGLEY, of Aby (well-sinker).

	feet.
Gravel	24
Clay	12
Sand	18
Chalk rock	12
	66

Another well in Chapel Street N.W. of the Church is only 42 feet deep, through clay into gravel with water.

ALFORD. At the New Grammar School, made in 1880.

Dug 20 feet, bored 18 feet.

	feet.
Through dark purple-brown Boulder Clay, into loose gravel with water	38

ALFORD. Well at a new house in the south part of the town.

Communicated by J. BINGLEY, of Aby (well-sinker).

	feet.
Small gravel and sand	20
Marl	9
Gravel	12
Hard chalk	9
	50

The surface of the chalk here is at nearly the same depth as in Mr. Soulby's well; it may therefore be part of the same mass.

ANDERBY. At the Rectory (Mr. Bond's).

Communicated by TH. NEWTON, of Anderby (well-sinker).

Dug 12 feet, bored 80 feet.

	feet.
Marl (Boulder Clay)	68
Sand	9
Chalk	15
	92

ANDERBY. At Mr. W. Budibent's Farm.

Communicated by TH. NEWTON, of Anderby (well-sinker).

Dug 9 feet, bored 86 feet.

	feet.
Marl (Boulder Clay)	71
Sand	10
Chalk	14
	95

ANDERBY. At Mr. Robinson's Farm, west of Anderby Creek.
Communicated by TH. NEWTON, of Anderby.

		feet.
POST-GLACIAL.	Buttery clay	20
	Sand and gravel	4
GLACIAL.	Hard marl (Boulder Clay)	52
	Sand and chalk rubble	10
	Solid chalk rock	12
		98

AUTHORPE. At the brickyard three furlongs N.N.E. of Church.
Information from Mr. TURNER (proprietor).

	feet.
Loamy soil	2
Reddish-brown clay	8
Purple loamy clay	5
Purple clay, with stones	9
White marl, with stones	5
Sandy gravel	2
[? Clay and] yellowish sand	30
Chalk rock, touched	—
	61

BEESBY. At Mr. Wakefield's house.
Communicated by J. BINGLEY, of Aby (well-sinker).

	feet.
Clay, with stones	34
Sand	3
Clay, with stones	35
Sand and gravel	3
Chalk	15
	90

BEESBY. At the Vicarage.
Communicated by ROBERT HARRISON, of Woodthorpe (well-sinker).

	feet.
Clay [with stones]	63
Sand	9
Small chalk, mixed with sand	3
	75

BILSBY, near Alford, at Mrs. Kemp's house, two furlongs S.E. of the Church.
Communicated by J. BINGLEY, of Aby (well-sinker).

	feet.
Clay, with whites	73
Sand	3
Rock [Chalk]	12
	88

Another well at Bilsby was bored through 60 feet of clay, finding water in the sand below.

BILSBY. At the Hall near the Church.

Communicated by ROBERT HARRISON, of Woodthorpe (well-sinker).

	feet.
Clay, mixed with sand (Hessle Clay)	15
Clay, with stones (Purple Clay)	40
Sand	15
Chalk, touched	1
	75

BOOTHBY HALL. One mile east of Welton.

The house stands on a knoll of sand.

	feet.
Sand	22

BRINKHILL. At cottage in chalk quarry half a mile S.S.E. of Church.

Information obtained on the spot.

		feet.
CHALK, 28 feet.	Rough white chalk	16
	Red chalk, dark at the bottom	12
NEOCOMIAN, 34 feet.	Greyish-white soapy clay	4
	Red and brown sands	30
		62

BURGH. In a field about half way from the station to the town.

Communicated by J. BINGLEY, of Aby (well-sinker).

Dug 15 feet, bored 42 feet.

	feet.
Clay, with stones	31
Sand	4
Clay, with stones	20
Gravel	2
	57

BURGH. At Mr. Thornally's farm, one mile N.E. of Church.

Communicated by Mr. JABEZ GOOD, of Burgh.

No good water found.

		feet.
POST-GLACIAL, 10 feet.	Soft brick clay	8
	Peat, with large oak trees	2
GLACIAL BEDS, 48 feet.	Light-coloured clay, with small chalk stones	18
	A spring of salt water at this depth.	
	Liver-coloured clay, mixed with gravel and sand	30
	A second spring of salt water (? in gravel).	
? KIMERIDGE CLAY.	Blue clay, very dry, containing Ammonites	154
		212

BURGH. Wells near the Church.

Information obtained in the town.

	feet.
Soft sand (Glacial)	20

BURGH. At the farm about a mile S.S.E. of the Church.
Information from Mr. BLAND (tenant).

		feet.
POST-GLACIAL.—Soil and silty clay		6
GLACIAL.	Marly clay, with chalk-stones	5
	Gravel and sand, with water	1
		12

BURGH. Cottage near Fawker's House, half a mile N.E. of Church.

Information obtained on the spot.
Water rises to the surface.

		feet.
Yellow sandy silt	about	6
Bluish marly clay, with stones	,,	25
Sand and small gravel	,,	2
		33

GREAT CARLTON.

Communicated by J. BINGLEY, of Aby (well-sinker).
Dug 18 feet, bored 66 feet.

	feet.
Clay [Boulder Clay]	69
Sand	3
Rock [Chalk]	12
	84

CHAPEL. At Mr. Hodgson's.

Communicated by TH. NEWTON, of Anderby (well-sinker).
Dug 9 feet, bored the rest.

	feet.
Clay to marl [Post-glacial]	9
Marl [Boulder Clay]	60
Sand and gravel	10
Chalk	12
	91

CHAPEL BANK. At Mr. Rennie's.

Communicated by TH. NEWTON, of Anderby.

Dug 12 feet, bored the rest.

	feet.
Sand and clay	12
Marl [Boulder Clay]	54
Sand	10
Chalk	8
	84

CLAYTHORPE. At the railway station, sunk in 1877.

Communicated by Mr. CH. KIRKBY, of Great Northern Railway Company, Louth.

	feet.
Hard blue clay	12
Clean sharp sand, full of water	5
Hard clay	14
Dirty sand, full of water	6
	37

CLAYTHORPE. Near the railway station.

Communicated by J. BINGLEY, of Aby (well-sinker).

Dug 30 feet, bored 36 feet.

	feet.
Through clay (60 feet), into gravel (6 feet)	66

Bingley states that this well was dug at the junction of the sand and clay, one side of the well being sand and the other clay for a depth of 28 feet, a very curious arrangement.

CLAXBY. Farm at south end of Shaddy's Walk, one mile from the Church.

Information from the occupier.

	feet.
Through white chalk into red rock	108

CLAXBY. Well at the Rectory, close to the Church.

Information from TYSON (well-sinker), of Willoughby.

	feet.
Chalk in original well	66
Chalk bored by Tyson	15
	81

Found a supply of water without reaching the bottom of the chalk.

CLAXBY. Mr. Wright's farm, two furlongs E.N.E. of Church.

Communicated by TYSON (well-sinker), of Willoughby.

	feet.
Clay [Boulder Clay]	46
Sand, with water	2
Clay	9
Sand, with strong spring	3
	60

CLAXBY WOOD. House on Mr. Higgin's farm. See SKENDLEBY SALTER, for particulars of boring here.

COCKERINGTON. At Mr. Beverley's, in South Cockerington.

Communicated by J. BINGLEY, of Aby (well-sinker).

	feet.
Clay, with stones	18
Sand	6
Clay, with stones	60
Sand	6
Rock [Chalk]	21
	111

COVENHAM. At Birkett's Farm, three-quarters of a mile N.E. of St. Bartholomew's Church.

Information from Mr. BIRKETT.

Dug 12 feet, bored about 58 feet.

	feet.
Reddish clay with stones	30
Gravel and shingle	20
Brashy chalk	5 ?
Solid chalk	15 ?
	70

CUMBERWORTH. At West Field Lodge, five furlongs W.S.W. of Church.

Communicated by TH. NEWTON, of Anderby (well-sinker).

	feet.
Marl and clay, with chalk	60
Sand	6
Gravel and "croy"	3
Chalk	12
	81

DALBY. At Froghall, one mile north of Dalby Church.

Information obtained from Mr. RIGGALL (tenant).

	feet.
White chalk	25
Red chalk	12
Brown sand	5
	42

DOVENDALE. Well in the farmyard about nine furlongs west of Tathwell Church.

Information obtained from the foreman.

	feet.
Brown clay [Boulder Clay]	10
White and pink chalk	5
Red marl	5
Red sand and water	1
	21

DRIBY. At the High Barn one mile east of Driby.

Communicated by J. BINGLEY, of Aby (well-sinker).

The original well was dug to a depth of 67 yards, Bingley cleared out 25 yards of rubbish from the bottom of this, and then bored further for 45 yards. His account is as follows:—

		feet.
CHALK, 201 feet.	White chalk	190
	Red chalk	11
CARSTONE, 15 feet.	Greenish sand	15
TEALBY BEDS, 105 feet.	Hard shaly roach	21
	Brown sand	3
	Shaly roach, with beds of ironstone	73
	Ironstone	4
	Sand and water	4
KIMERIDGE CLAY.	Black shaly mud or clay, with a layer of coaly matter 7 inches thick — about	15
		336

NORTH ELKINGTON. At the farm formerly held by Mr. Kemp, near Boswell.

Communicated by CH. WILKINSON, of Louth (well-sinker).

	feet.
Bored through white chalk and "greystone" into red chalk	297

FIRSBY. Boring near railway bridge on the Wainfleet branch.

Information from Mr. WIELD, of Great Northern Railway, Louth.

	feet.
Reddish marly clay	9
Sand and gravel	2
Soft clay, with a few stones	7
Sand and gravel, with water	6
	24

FOTHERINGTON, near Ulceby. At Mr. Cartwright's farm.

Information from Mr. CARTWRIGHT, of Well.

	feet.
White and grey chalk	118
Red chalk	12
Brown sand, with water	5
	135

GAYTON. A farm in the marsh, two miles N.E. of the Church.

From information obtained on the spot.

		feet.
Warp clay	about	30
Silt	,,	10
Marl, with whites	,,	40
Croy and chalk	,,	10
		90

GAYTON-LE-MARSH.

Communicated by ROBERT HARRISON, of Woodthorpe (well-sinker).

	feet.
Surface soil	1½
Marly clay, yellow near the surface, harder below, and getting darker towards the bottom, with chalk stones and other pebbles	66
Clean sand	7½
Sand, with small chalk stones	3
	78

GREBBY. At cottages by Grebby Mill, half a mile N.W. of Scremby.

Information from the occupant; measured by myself.

	feet.
Brown sand	34
Bluish clay	3
	37

GRIMOLDBY. At Pickhill Farm, bored in 1862.

Communicated by ROBERT HARRISON, of Woodthorpe (well-sinker).

	feet.
Yellow clay	6
Marly clay	30
Grey sand	16
Dark clay, with small chalk stones and pebbles	27
Sand	8
Loose chalk	3
	90

GRIMOLDBY. At a house near the Plough Inn.

Communicated by the tenant, who made the boring himself.

	feet.
Dug in marl	10
Bored through marl	60
Chalk rubble	9
	79

He had also bored a well at a farm on the border of the Marshland one mile N.E. of Grimoldby Church; the depth to the Chalk being 72 feet and the water overflowing to height of 7 feet.

GRIMOLDBY. At the schools.

Communicated by J. BINGLEY, of Aby (well-sinker).

	feet.
Dug in clay	11
Bored in clay Sand and rubble	75
Chalk rock	9
	95

GUNBY. At the cottage N.E. of the Church.
Information from ALISON, the foreman.

	feet.
Brown clay, with sand at the bottom	25

GUNBY. At cottage half a mile south of Church.
Information from ALISON, the foreman.

	feet.
Brown clay into sand	40

GUNBY. At the Hall.
Information obtained on the spot.

	feet.
Bored through clay into sand	70

Probably through Tealby Clay into the Spilsby Sandstone.

HABERTOFT. A mile and a half N.W. of Orby.
Information from Mr. DAWSON (the tenant).

	feet.
Clay, with stones [Boulder Clay]	20
Sand and water	4
	24

HANNAH. Near the Church.
Communicated by J. BINGLEY, of Aby (well-sinker).

	feet.
Clay [Boulder Clay]	about 70
Sand	,, 6
Chalk rock	,, 21
	97

HAGWORTHINGHAM. At Mr. Swaby's house, a quarter of a mile N.W. of the church.
Information from BROOKS (well-sinker).

	feet.
Yellow clay [Boulder Clay]	4
[NEOCOMIAN] Sand, with hard rock at bottom	50
	54

HAGWORTHINGHAM. At a farm called Westerby, one mile W. of Hagg.
Communicated by BROOKS (well-sinker).

		feet.
White clay [Boulder Clay]		20
SPILSBY SANDSTONE	Sand rock	4
	Sand	30
		54

HELSEY, near Hogsthorpe. At Mr. Payne's.

Communicated by TH. NEWTON, of Anderby (well-sinker).

	feet.
Marl (dug and bored)	54
Sand on the rock	10
Chalk	10
	74

HOGSTHORPE. At the windmill, half a mile east of Church.

Information from the Miller.

Water rises to within 11 feet of surface.

Well dug 22 feet, bored the rest.

		ft.	in.
HESSLE BEDS, 14 feet.	Loamy marl	8	0
	Sand, with water	2	0
	Red marl	3	9
	Thin seam of gravel	0	3
PURPLE CLAY, 68 feet.	Bluish marl	64	0
	Sand and rubble	4	0
	Chalk rock	2	0
		84	0

In the village the wells are only from 12 to 14 feet deep, water being found in the upper bed of sand, in the Hessle Clay. At the brickyard north of Hogsthorpe, Mr. Spalding stated that his well was dug and bored about 80 feet through clay into the chalk.

HUTTOFT BANK. At Mr. Needham's farm.

Communicated by TH. NEWTON, of Anderby (well-sinker).

		feet.
POST-GLACIAL, 25 feet.	Sand and silt	10
	Soft clay	15
GLACIAL BEDS, 50 feet.	Marl	42
	Sand and gravel	8
	Chalk	14
		89

HUTTOFT. At the Steam-mill.

Communicated by J. BINGLEY, of Aby (well-sinker).

Dug 14 feet, bored the rest.

	feet.
Clay [Boulder Clay]	65
Sand and gravel	6
Rock [Chalk]	12
	83

HUTTOFT. At Mr. Lutey's farm.

Communicated by TH. NEWTON, of Anderby (well-sinker).

	feet.
Dug in marl	12
Bored in marl	54
Sand on the chalk	10
Chalk	12
	88

HUTTOFT. At Mr. F. Robinson's Farm.

Communicated by TH. NEWTON, of Anderby.

	feet.
Dug in marl	10
Bored in marl	48
Sand	14
Croy and chalk	12
	84

HUTTOFT. At Mr. J. Bradley's farm.

Communicated by TH. NEWTON, of Anderby.

	feet.
Marl (bored from surface)	62
Sand and gravel	12
Croy and chalk	14
	88

INGOLDMELLS. At the mill (Mr. Stone's).

Communicated by TH. NEWTON, of Anderby (well-sinker).

	feet.
Soft buttery clay	40
Marl (Boulder Clay)	16
Sand	10
Chalk	12
	78

KEAL. Several wells at houses along main road N. and W. of East Keal Church.

Information from CHESTER (well-sinker).

	feet.
Soft yellow and green sandstone	30 to 35
Soft green sand, with water	3 to 4
Blue clay below	—
	33 to 39

EAST KIRKBY. At house near corner of roads.
Information from Mr. ORBY, of Kirkby.

	feet.
Through gravel and silt to blue clay - - -	30

LANGTON GRANGE. 1½ mile, N.N.E. of Langton.
Information from Mr. MACKINDER (tenant).

	feet.
White chalk - - - - - about	100
Red chalk - - - - - ,,	13
Brown sand - - - - - ,,	16
	129

OLD LEAKE, five furlongs N.E. of the railway station, "a boring made by Mr. Welsh of Boston in 1867 at a point on the East Lincolnshire Railway, seven miles southward from the Steeping River."
Communicated by the late Mr. SEARLES V. WOOD.

		Feet from surface.	Thickness.
FEN BEDS	Brown clay - -	3·94	feet.
	Peat - - -	4·19	
	Soft blue clay -	7·68	8
	Peat - - -	8·01	
HESSLE BEDS	Strong marly clay -	16·48	
	Coarse yellow sand, with water - -	20	12
KIMERIDGE CLAY.	Hard blue clay -	29	9
			29

The strong marly clay said to contain "occasional bits of water-worn "gravel and clear coarse yellow sand."

LOUTH. Boring at the Waterworks, opposite Thorpe Hall, W.S.W., of Louth Church.
Communicated by H. ROBINSON, C.E., from a drawing made in December 1871, by T. W. WALLIS, C.E., of Louth.

		ft.	in.
ALLUVIUM, 9 feet.	Silty mould - -	3	0
	Marl, sand, and clay - -	6	0
CHALK, 20 feet.	White marl or chalk - -	2	0
	Red marl - - - -	1	0
	White marl or chalk - -	5	9
	Red marl or chalk - -	7	3
	Softer red chalk and clay - -	4	0
CARSTONE, 29 feet.	Yellowish clay and sand - -	4	0
	Coarse red sandstone - -	11	0
	Dark reddish sand - -	6	0
	Yellow sand - - -	8	0
		58	0

Water was found in the red chalk from a depth of 17 to 25 feet, but very little came in from the sands below.

LOUTH. At the Windmill, half-a-mile N.E. of Church.

The Miller states that his well is between 65 and 70 feet deep, entirely through clay into sand, with good water; and that the chalk was not touched.

LOUTH. In Little Lane, Mount Pleasant.

Communicated by J. BINGLEY, of Aby (well-sinker).

Dug 39 feet, bored 21 feet.

	feet.
Red-brown clay, with stones	4
Silt	1
Purple clay, with stones	49
Chalky gravel	3
Chalk rock	3
	60

LOUTH. In Victoria Road, near the Railway Station.

Communicated by BURTON (well-sinker), Louth.

Dug 24 feet and bored about 24 feet.

	feet.
Reddish clay	8
Sand	4
"Blue" clay	36
[Gravel ?]	?
More than	48

LOUTH. At Mr. Kiddell's, near Trinity Church.

Communicated by BURTON (well-sinker).

	feet.
Gravel	15
Clay	30
	45

LOUTH. At Mr. Hyde's farm, on the road to Legbourn, a mile and a half S.E. of Louth Church.

Communicated by BURTON (well-sinker).

Water overflows.

	feet.
Through clay to chalk	75

LOUTH. At houses on road to Legbourn, about a mile and three-quarters from Louth Church.

Communicated by BURTON (well-sinker).

Water overflows.

	feet.
Through clay to chalk rock	90

LOUTH. At Mr. Dickie's brickyard, three-quarters of a mile S.S.E. of the Church, in the valley.

Communicated by Mr. DICKIE.

"The well was dug 18 feet, bored 32 feet, in all about 50 feet from the surface to the chalk rock; through solid marl with small patches of sand here and there, but no regular beds. Water in abundance as soon as the chalk was tapped."

A well at the brickyard east of the railway station is said to be dug 27 feet and bored 30 feet through clay to chalk.

LOUTH. At a house near the parish Church.

Communicated by CH. WILKINSON (well-sinker), of Louth.

Dug 21 feet, bored 24 feet.

	feet.
Clay, with chequers	27
Chalky gravel	5
Blue clay	6
Sand	2
Chalk and water	5
	45

LOUTH. Well by the lamp-post in Eastgate, near the Market Place.

Communicated by CH. WILKINSON (well-sinker), of Louth.

Dug 21 feet, bored 24 feet.

		feet.
Blue clay, with whites [Purple Clay]	about	39
Gravel and sand	,,	4
Chalk rock and water	,,	2
		45

Another account of the same well by J. Bingley, of Aby, makes it 50 feet deep, through dark purple clay into sand.

LUSBY. At a house near the main road.

Communicated by Mr. BROOKS, of Hagworthingham (well-sinker).

		feet.
	White clay [Boulder Clay]	30
SPILSBY SANDSTONE.	Ragstone	5
	Sand and water	5
		40

MABLETHORPE. Boring made in 1878.

Communicated by Mr. T. W. WALLIS, surveyor, Louth.

Water rose to within four feet of the surface.

		feet.
POST-GLACIAL, 46 feet.	Stiff clay	8
	Softer clay	3
	Buttery clay	8
	Soft black boggy clay	27

		feet.
Glacial, 37 feet.	Stiff clay (Boulder Clay)	20
	Sandy clay	4
	Stiff clay, with small chalk débris	7
	Chalk rubble	6
	Solid chalk	12
		95

Mablethorpe. Boring made in 1881 near the shore.

Communicated by Robt. Harrison, of Woodthorpe (well-sinker).

		feet.
Post-glacial, ? 63 feet.	Sand (? blown sand)	6
	Dark blue silt	45
	Dark brown warp clay	4½
	Grey sand	7½
Glacial, 54 feet.	Clay, with chalk stones	18
	Sand, mixed with clay	12
	Clean grey sand	6
	Coarse sand and small gravel	12
	Gravel of chalk and flint	6
	Chalk	20
		137

Harrison says that this and that at Theddlethorpe are the deepest borings he has ever made in the Marsh. There seems to be a valley or depression in the Chalk here below the Drift.

Mablethorpe. At the schools, bored in 1879.

Communicated by Robt. Harrison, of Woodthorpe (well-sinker).

		feet.
Post-glacial, 28 feet.	Surface clay	4
	Soft warp	22
	Turf	2
Glacial, 54 feet.	Dark clay, with small stones	45
	Grey sand	6
	Loose chalk	3
		82

Mablethorpe. At the brickyard, 350 yards N.E. of the Church.

Communicated by Joseph Jacklin, of North Cotes (well-borer).

		feet.
Post-glacial Beds, 48 feet.	Firm clay	9
	Soft black clay	36
	Sand	2
	Peat	1
Glacial Beds, 31 feet.	Marl [Boulder Clay]	30
	Sand	1
	Hard chalk	24
		103

MABLETHORPE. At Ingoldsby Cottage, bored in 1863.

Communicated by ROBT. HARRISON, of Woodthorpe (well-sinker).

		feet.
POST-GLACIAL, 48 feet.	Surface clay	5
	Bluish silt	43
GLACIAL, 60 feet.	Marly clay	24
	Grey sand	36
		108

MALTBY, near the brickyard, N. of Maltby.

Communicated by ROBT. HARRISON, of Woodthorpe (well-sinker).

	feet.
Clay	52
Sand (clean)	15
Sand, with small chalk stones	3½
	70½

MANBY. Well at the Hall, bored in 1857.

Communicated by ROBT. HARRISON, of Woodthorpe (well-sinker).

	feet.
Surface soil	1
Yellow clay	3
Marly clay, with many pebbles, darker in colour towards the bottom	66
Sand	8
Loose chalk	4
Firm chalk at bottom	3
	85

MARKBY. At the Rectory (Rev. J. Allott).

Communicated by ROBT. HARRISON, of Woodthorpe (well-sinker).

	feet.
Clay [with stones]	57
Sand (clean)	7
Sand, with small chalk stones	2
	66

MARKBY. At Mr. Davey's (?) Farm, near Hannah.

Communicated by ROBT. HARRISON, of Woodthorpe (well-sinker).

	feet.
Clay [with stones]	63
Clean sand	4
Sand, mixed with chalk	2
	69

MARKBY. At Mr. Robinson's.

Communicated by J. BINGLEY, of Aby (well-sinker).

Dug 15 feet, bored 60 feet.

	feet.
Clay [Boulder Clay]	63
Sand	3
Rock [Chalk]	9
	75

MAVIS ENDERBY. Cottage at corner of road, about 500 yards S.W. of the Church.

Information from the occupant.

	feet.
Yellowish clay (Middle Neocomian)	9
Sandstone (bored)	30
Hard "rock-stone" (blasted), with water beneath	1
	40

MAVIS ENDERBY. At new cottages by Northfield Farm, about five furlongs N.W. of Enderby Church.

Information from Mr. BROWN (the tenant).

	feet.
Yellow clay, with stones (Boulder Clay)	16
Sand with water (Lower Neocomian)	7
	23

ORBY. At a house near the Inn, S.E. of the Church.

Communicated by J. BINGLEY, of Aby (well-sinker).

Dug 10 feet, bored 35 feet.

	feet.
Clay, with stones	15
Sand	3
Clay, with stones	24
Gravel of small chalk pebbles	3
	45

ORBY. At the Vicarage.

Information obtained in the village.

Well dug 17 feet, bored 5 feet.

	feet.
Clay, with stones	22
Gravel, with plenty of water	2
	24

At the "Red Lion" Inn there is gravel at a depth of 12 feet.

ORBY. Mr. Grantham's farm, seven furlongs S.E. of Church.

Well dug 16 feet, bored 20 feet.

	feet.
Clean clay - - - - - about	6
Marly clay - - - - - -	28
Gravel - - - - - - -	2
	36

SOUTH ORMSBY. At cottage opposite the Church.

	feet.
Sunk through stiff clay, with stones and veins of sand, water found at bottom - - -	45

SOUTH RESTON. At the brickyard, bored in 1870.

Communicated by ROBT. HARRISON, of Woodthorpe (well-sinker).

	feet.
Soil, &c. - - - - - -	3
Clay, with small stones - - - -	25 ?
Grey sand, with very small gravel - - -	3
Dark clay, with stones - - - -	26
Grey sand - - - - - -	8
	65

RUCKLAND. At the Vicarage.

Information obtained at Ruckland.

	feet.
Sunk through grey into red chalk - - -	28

SALEBY. At the Vicarage.

Communicated by ROBT. HARRISON, of Woodthorpe (well-sinker).

	feet.
Clay [with stones] - - - - -	59
Sand - - - - - - -	12
Sand, with flints - - - - -	2
	73

SALEBY. At Mr. Farrar's.

Communicated by J. BINGLEY, of Aby (well-sinker).

	feet.
Clay with stones - - - - -	67
Gravel - - - - - - -	6
Rock [Chalk] - - - - - -	10
	83

Another well (at Mr. Riggall's) pierces clay 66 feet and gravel 9 feet, finding a supply of water without touching the chalk.

SALTFLEET. Average thickness of beds down to the surface of the chalk in wells near Saltfleet.

Communicated by CH. WILKINSON (well-borer), of Louth.

	feet.
Warp clays	24
Stony brown clay [Boulder Clay]	60
Sand with sea-shells	2
Chalk below.	

SALTFLEETBY. At the railway station, half-a-mile west of Saltfleetby, All Saints.

Communicated by Mr. W. H. KIRKBY, of the Engineers' Office, Great Northern Railway, Louth.

	feet.
Soft black soil [Clay and Silt]	42
Hard red clay [Boulder Clay]	28
Sand	2
White chalk [and ? Red Chalk]	18
Sand [? Neocomian]	35
	123

If this is a correct account it shows that the thickness of Chalk beneath the drift is less than I thought likely when drawing the section No. 1 (see Plate). Water was found about midway in the Chalk, at a depth of 80 feet from the surface. It is possible, however, that the chalk is a detached mass, and that the sand below is Glacial.

SALTFLEETBY. At the brickyard, three-quarters of a mile S.W. of St. Peter's Church.

Communicated by Mr. J. CANNON (proprietor).

Dug 30 feet, bored 66 feet.

		feet.
POST-GLACIAL	Brown and black clays	10
	Turf, with trees	0¾
	Sandy clay, with flint stones	2
BOULDER CLAY	Marl, full of whites	74
	Croy and chalk	10
		96¾

SCREMBY. At Mr. Forster's house, a quarter of a mile S.E. of the Church.

Information from WOODS (well-sinker), Scremby.

Water rises to the surface.

	feet.
Brown clay, with chalk and stones, dug for	16
Bored through same into chalky gravel	17
	33

SCREMBY. Well in farmyard, a quarter of a mile north of the Church.

Information from WOODS, of Scremby.

	feet.
"Roach," a loam clay, or soft ironstone Red sand below, with water	40

SKENDLEBY SALTER, north of Skendleby.

Information from Mr. BELTON (tenant).

	feet.
Dug in a hard rock like ironstone - - -	104

No spring was reached here, but water trickles in from the side some way down. The lower part is probably in hard clay, like the following:

SKENDLEBY SALTER. At cottage on Mr. Higgin's farm, half a mile east of last.

Communicated by CH. WILKINSON, of Louth (well-sinker).

Dug 22 yards, bored 30 yards.

	feet.
4. Chalk rubble - - - - -	6
3. Brown soft sandstone [? and ironstone] - -	24
2. Black clay, dug for - - - -	36
1. Same clay bored to - - - -	90
	156

Two large oyster shells were found at the bottom of the dug well; no spring reached in the boring. Tyson, of Willoughby, describes a bed of hard bluish rock, drying grey and flaky, "with silvery chips in it," as occurring in this well, probably at the base of the sandstone.

SKEGNESS. Boring at the new waterworks, about a quarter of a mile N. of the Church.

Communicated by Messrs. S. F. BAKER AND SONS.

		ft.	in.
POST-GLACIAL, 32½ feet.	Surface soil - - -	3	6
	Loamy clay - - -	2	0
	Black and brown mud - -	27	0
GLACIAL BEDS, 18½ feet.	Brown clay, with stones - -	2	3
	Dry gravel - - -	1	3
	Brown clay - - -	8	6
	Dry sand and gravel - -	6	6
CHALK, 33 feet.	Chalk rock, with salt water -	9	6
	Hard chalk rock, without water -	11	6
	Red chalk, pink above, dark red below - - - -	12	0
CARSTONE, 18 feet.	Red marl and sand - -	8	0
	Dead greensand - - -	6	6
	Fine dark greensand - -	2	0
	Loamy greensand - - -	1	6
"ROACH" BEDS, 28½ feet.	Hard light-coloured clay - -	6	6
	Blue clay - - - -	8	6
	Sandstone shale - - -	13	6

		ft.	in.
Middle Neocomian Clay, 191 feet.	*Pale and greenish clays with silty bands, scattered oolitic grains of iron oxide occur throughout	96	0
	Pale bluish-grey clay, with small white shell-fragments and occasional septarian nodules	43	0
	Green silt and clay	17	0
	Greyish-blue clay	4	0
	Buff and pinkish silt, becoming brown below, and containing oolitic grains of iron oxide	5	0
	Tough blue clay, with numerous grains of quartz	2	0
	Light blue clay, with fine white sand	2	0
	Stone band	0	6
	Hard dark-blue clay	10	6
	Light blue clay and silt	6	0
	Stone band	0	6
	Hard light-coloured clay	1	6
Spilsby Sandstone, 19 feet.	Grey sand, with water†	2	0
	Brown sand and sandstone, with thin clay band, containing numerous grains of iron oxide and shell fragments (*Pecten cinctus* and *Belemnites*)	10	0
	Greenish sand, containing iron grains, with a pale-blue stony band, containing specks of iron-pyrites	7	0
Age doubtful, 23 feet.	Pale-blue clay, with a hard stone band, containing fragments of shells, specks of iron-pyrites and ? oolitic grains of iron oxide	23	0
Kimeridge Clay.	Dark-blue clay, with bivalves and Ammonites	42	0
		405	0

North Somercotes.

Communicated by Ch. Wilkinson (well-sinker).

Post-glacial, 58 feet.	Reddish clay	4
	Black moor and sand	50
	Sand and shells	4
Glacial, 44 feet.	Layers of red clay, sand, and gravel	44
	Chalk, soft at the top with "greystone" at the bottom	40
		142

* To a depth of 130 feet the details are from a section by the well-borers first engaged (Messrs Le Grand and Sutcliffe) in the office of the waterworks; below this from specimens sent to my colleague, Mr. A. Strahan, from time to time, as the boring progressed, and examined by him.

† Water rose from this bed to 6 feet above the surface, yielding 8 gallons a minute.

SOUTH SOMERCOTES.

Communicated by JOSEPH JACKLIN (well-borer), of North Cotes.

		feet.
POST-GLACIAL, 52 feet.	Firm clay	18
	Soft black clay	30
	Sand	4
GLACIAL, 34 feet.	Firm clay	12
	Sand	6
	Firm clay	15
	Sand	1
	Chalk, rather soft	38
		124

At this depth the rods struck a hard rock which they would not penetrate.

SOUTH SOMERCOTES. At Mr. Michael's farm.

Obtained from a well-sinker in Saltfleet.

		feet.
POST-GLACIAL, 34 feet.	Brown silt	30
	Sand	4
GLACIAL, 56 feet.	Clay, with stones	about 54
	Sand	,, 2
CHALK, 36 feet.	Chalk rock (hard)	6
	Soft chalk, with a hard stone at the bottom	30
		126

SPILSBY. At house in the Newtown, about two furlongs E.S.E. of the Church.

No water found.

	feet.
Dug and bored through blue clay	90

Another well at the "King's Head" Inn was bored to the same depth.

STEEPING. At cottage on the north side of railway, near Steeping Mill.

Information obtained on the spot.

	feet.
Boulder Clay	18
Gravel, with water	about 2
	20

STRUBBY. At Mr. Dowse's.

Communicated by ROBT. HARRISON, of Woodthorpe (well-sinker).

	feet.
Clay, red and marly	30
Sand	3
Black clay, with small chalk and other pebbles	6
Sand	12
	51

STRUBBY. At house half a mile south of the Church.

From information obtained on the spot.

	feet.
Through reddish clay to sand - - -	30

SUTTON. At the new Vicarage, bored in 1879.

Communicated by ROBT. HARRISON, of Woodthorpe (well-sinker).

		feet.
POST-GLACIAL, 26 feet.	Surface soil - - - -	3
	Soft warp clay - - -	18
	Turf - - - - -	3
	Sand and small gravel - -	2
GLACIAL, 53 feet.	Clay, with very small "whites" -	25
	Grey sand - - - -	3
	Dark clay, with small stones -	12
	Gravel (with water) - - -	1½
	Black clay - - - -	5
	Green sand - - - -	5
	Grey sand and small gravel - -	1½
	Soft loose chalk - - -	2
		81

SUTTON. Recorded in *Phil. Trans.*, vol. 89, p. 145 (1799).

	feet.
Clay - - - - - - -	16
Moor, like that of the islets - -	3 to 4
Soft moor, mixed with shells and silt - -	20
Marly clay - - - - - -	1
Chalk rock - - - - - -	1 to 2
Clay - - - - - - -	93
Gravel and water (chalybeate taste) - -	—

This does not read like a truthful record, the depth of clay given being much more than is found anywhere in the neighbourhood.

SUTTON. Two wells, A. at Mr. Wood's, B. at Mr. Brown's, near the Inn N. of the Church.

Communicated by J. BINGLEY, of Aby (well-sinker).

		A. feet.	B. feet.
POST-GLACIAL.	Dug in soft brown clay -	7	7
	Bored in the same -	33	30
	Bed of turf - - -	3	3
GLACIAL.	Strong brown clay, with chalk stones and other pebbles -	36	39
	Clean sharp sand - -	3	4
	Gravel - - - -	3	2
	Brown clay, with stones -	21	none
	Chalk - - - -	16	15
		122	100

SUTTON. Trial-hole, made in 1885, opposite the Sandhill, near the Church.
Surface at about High-water mark.
Communicated by Mr. R. ELLIOTT COOPER.

		ft.	in.
POST-GLACIAL	Soil	1	0
	Brown clay	7	6
	Blue clay	8	10
	Peat	1	6
	Blue clay	1	3
GLACIAL	Hard marly clay (not bottomed)	17	11
		38	0

SWABY. Cottage by Windmill, three furlongs W.S.W. of Swaby.
Information obtained from the Miller.

	feet.
Dug in brown clay, with rubble at base	10
Bored in chalk, grey, with pink bands	58
	68

TATHWELL. At Mr. Smith's (Tathwell Hall).
Communicated by J. BINGLEY, of Aby (well-sinker).

	feet.
White chalk	54
Red chalk	15
Brown sand	24
	93

THEDDLETHORPE. At the Rectory, bored in 1863.
Communicated by ROBT. HARRISON, of Woodthorpe (well-sinker).

		feet.
POST-GLACIAL, 46 feet.	Surface clay	6
	Soft mud	40
GLACIAL, 42 feet.	Marly clay	26
	Hard silt	6
	Dark clay, with small stones	2
	Sand	8
	? White putty or soft chalk	25
		113

THEDDLETHORPE. At Mr. J. P. BADLEY'S, bored in 1870.
Communicated by ROBT. HARRISON, of Woodthorpe (well-sinker).

		feet.
POST-GLACIAL, 36 feet.	Surface clay, rather sandy	7
	Grey sand	29
GLACIAL, 42 feet.	Yellow clay (with stones?)	about 10
	Dark clay, with pebbles and chalk stones	about 26
	Grey sand	8
	Loose chalk	5
		85

THORPE CULVERT. At a house called Fendyke, a mile and a quarter west of the railway station.

Information obtained by Mr. SKERTCHLY.

	feet.
Soil and fen clay	7
Peat, full of wood	3
"Clean" clay [partly Boulder Clay?]	30
Sand, with water	—
	40

SOUTH THORESBY. At the shop, about 300 yards S.W. of Church.

Communicated by J. BINGLEY, of Aby (well-sinker).

	feet.
Sand and gravel	9
Clay, with layers of gravel	about 15
Gravel	,, 7
Chalk	6
	28

SOUTH THORESBY. Well in Mr. North's garden, not far from the above.

Communicated by J. BINGLEY, of Aby (well-sinker).

	feet.
Clay, with chalk and stones	21
Sand and gravel, with water at bottom	8
	29

THURLBY. About two miles E. of Alford, at Mrs. Kemp's.

Communicated by J. BINGLEY, of Aby (well-sinker).

Dug 11 feet, bored the rest.

	feet.
Clay [Boulder Clay]	59
Sand	3
Rock [Chalk]	15
	77

ULCEBY. At the Grange Farm (Mr. Riggall's).

Information from Mr. CARTWRIGHT, of Well.

	feet.
White and grey chalk	180
Red chalk, with a little water	10
	190

WALMSGATE. At the farm half a mile W.S.W. of the Hall.
Information from the foreman.

	feet.
Dug through clay with stones into sand	36

WELL. At Mr. Cartwright's, three furlongs N.E. of the Church.
Information from Mr. CARTWRIGHT.
Water rose to the surface.
Dug 25 feet, bored 40 feet.

	feet.
Clay, with stones	55
Gravel of chalk and flints	4
Solid chalk	6
	65

WELTON. Between Gunby and Willoughby. At house, one furlong N.W. of the Church.
Information from J. TUTTY, well-sinker.
No water obtained.

	feet.
In clay with stones	36

At the Inn he bored 27 feet through clay into gravel, with water.
At the houses, two furlongs N.W. of the Church, he made two wells:

	A. feet.	B. feet.
Brown clay	6	7
Soft marl	10	10
Solid chalk	20	23
	36	40

WELTON MILL. Three-quarters of a mile west of the Church.
Information obtained on the spot.

	feet.
White and grey chalk	92
Red chalk, with water	10
	102

WELTON. Thwaite Hall, near Welton Wood.

	feet.
Clay, with stones	about 35
Hard chalk gravel	12
Sand and water	3
	50

WILLOUGHBY. At Tyson's cottage, 400 yards west of the station, the well sunk by himself.

	feet.
Clay full of chalk stones and thin veins of sand	30
Soft chalky clay or marl	6
Clay, with chalk stones	12
Sand, with water	2
	60

WILLOUGHBY RECTORY, near the Church.

Information from TYSON, of Willoughby (well-sinker).

	feet.
Dug through gravel and clay - - - -	18
Clay with stones, Sand at bottom } bored - - - -	40
	58

WILLOUGHBY MILL. Half a mile S.E. of the Church.

Information from TYSON, of Willoughby (well-sinker).

	feet.
Sunk through clay with small chalk stones, into sand - - - - - - - -	15

WITHCALL. At the back of Mr. Soulby's farmyard (S.W. of the Church).

Communicated by CH. WILKINSON, of Louth (well-sinker).

	feet.
Sunk through pink chalk into greyish-white chalk, without piercing the latter, but finding water at -	21

WITHCALL. Well on the railway, near the station.

Communicated by Mr. W. H. KIRKBY, of the Engineers' Department, Great Northern Railway.

	feet.
White chalk - - - - - -	19
Red chalk (water at bottom) - - - -	8
	27

WITHERN, about half a mile west of the Church.

Communicated by J. BINGLEY, of Aby (well-sinker).

Dug 24 feet, bored 66 feet.

	feet.
Clay, with stones - - - - -	78
Sand and gravel - - - - -	12
	90

WITHERN. At Mr. Well's farm, two furlongs S.E. of Church.

Communicated by ROBT. HARRISON, of Woodthorpe.

	feet.
Clay, with stones - - - - about	50
Sand - - - - - - ,,	15
	65

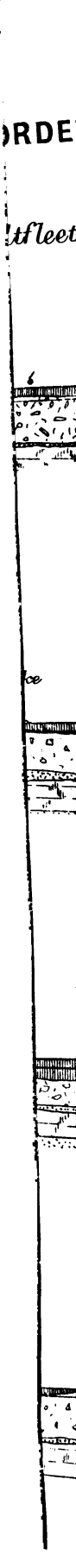
WOODTHORPE. At Mr. Kelk's farm, a mile and a half west of Beesby.
Communicated by R. HARRISON, of Woodthorpe.

	feet.
Surface soil	2
Yellow silt	19
Sand and small gravel	3
Dark coloured clay	24
Black clay, with small stones	38
Sand and small gravel	6
Loose chalk and flints (" croy ")	6
	98

YARBOROUGH, near the Carpenter's shop.
Communicated by CH. WILKINSON (well-sinker), Louth.

	feet.
Red and blue (? purple) clay	30
Gravel	10
Sand	9
Blue (? purple) clay	5
Sand and clay	10
Chalk	6
	70

INDEX.



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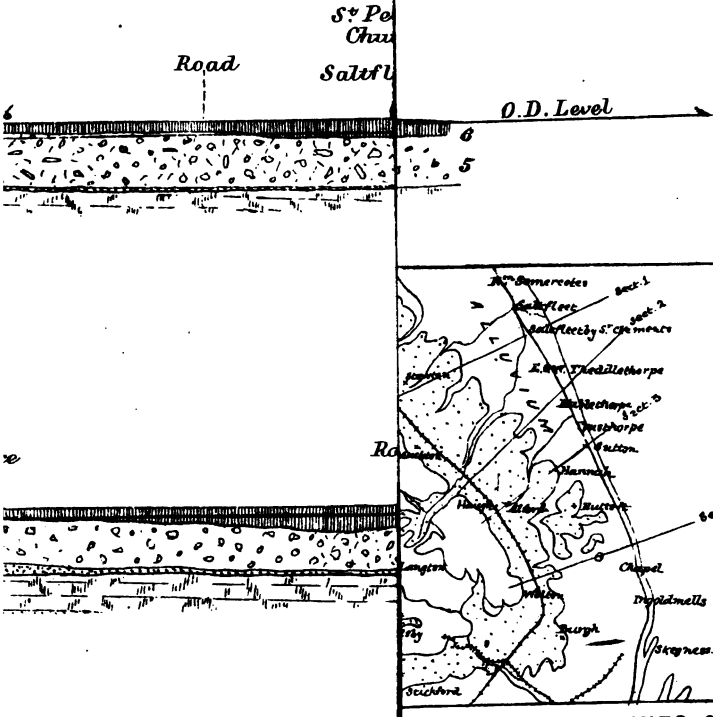

MAP SHOWING THE LINES OF SECTION.

ed portions indicate the surface areas
ied by the Glacial Deposits.

alk.

lay.

2 Miles.

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